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PREPARED RADIO MEASUREMENTS

WITH SELF-COMPUTING CHARTS

By RALPH BATCHER

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PREPARED
RADIO MEASUREMENTS
WITH SELF-COMPUTING CHARTS

By
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326 BROADWAY WIRELESS PRESS INC. NEW YORK

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WIRELESS PRESS, Inc.

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OCT 31 1921

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Introduction

A LARGE amount of radio equipment is constructed by amateurs with the cut and try method, and even the commercial and engineering fields are not free from users of this method. An English textbook on higher mathematics states that "Good guessing is a fine art," but not every radio experimenter is an artist, so there is a field for a book that is devoted entirely to simplifying the methods of determining electrical and geometrical constants for radio instruments and appliances.

The charts included in this book represent formulae that are apt to occur in ordinary radio computations. Some of these have doubtless been neglected on account of their relative complexity heretofore, but it is hoped that with a simplified method of obtaining a solution they will become more valuable.

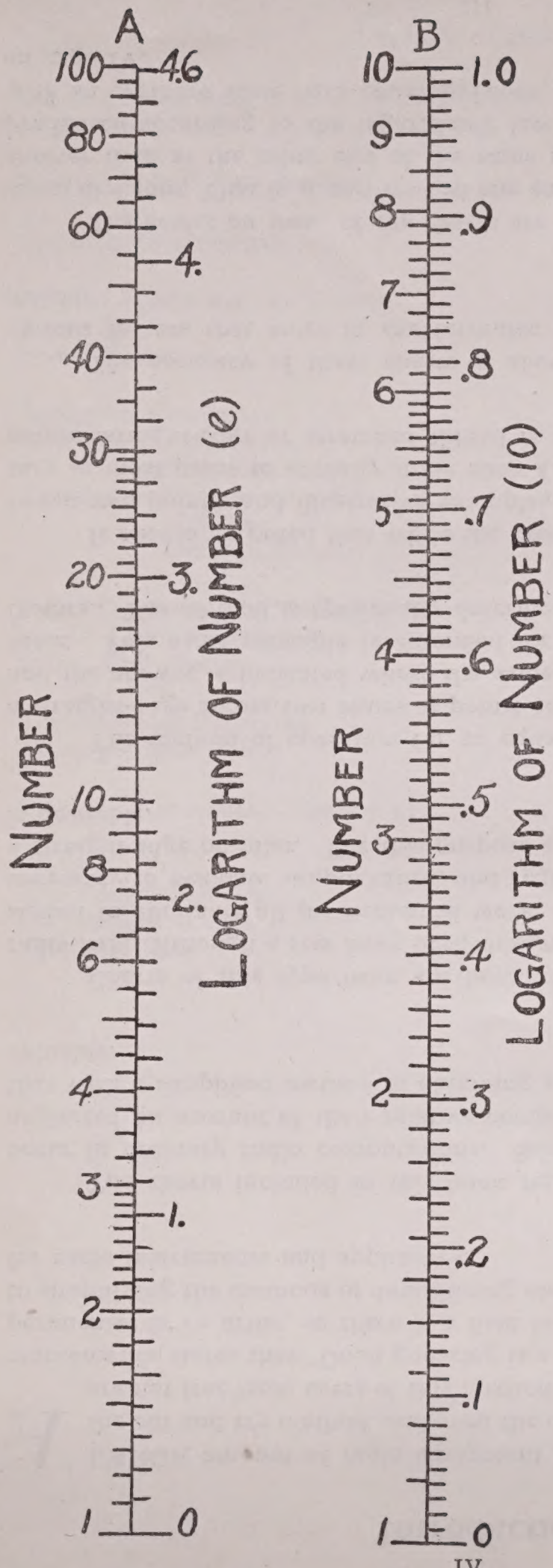
Charts of this type have not been used extensively heretofore in the radio field, although a few have been designed and published. They are designed to eliminate all mathematical work, except in a few cases when it is necessary to evaluate simple ratios, and require no special equipment except a straight-edge or ruler. For this purpose a transparent draftsman's triangle is desirable.

The method of operation for an equation with three factors is to lay a straight-edge across two scales at points corresponding to the known values and the answer is indicated where the same straight line intersects the third scale. This same principle is extended for charts containing four or more factors. The method is specifically described with each chart.

It should be noted that while the description may call for a "line" between two points, and illustrative examples show such a line, it is unnecessary in most cases to actually draw such a line in with a pencil if a transparent straight-edge or stretched thread is used.

The accuracy of these charts is above the accuracy with which the various factors that enter in the formulas can be measured with ordinary means.

The scales on most of the charts are of necessity graduated with unequal divisions. That is, a unit toward one end of the scale may be very much shorter than at the other end of the same scale. Many of these scales are graduated according to the logarithmic law. A comparison of such a scale with an ordinary scale with equal divisions, such as on a foot ruler, is given on page IV.



Method of Using Charts

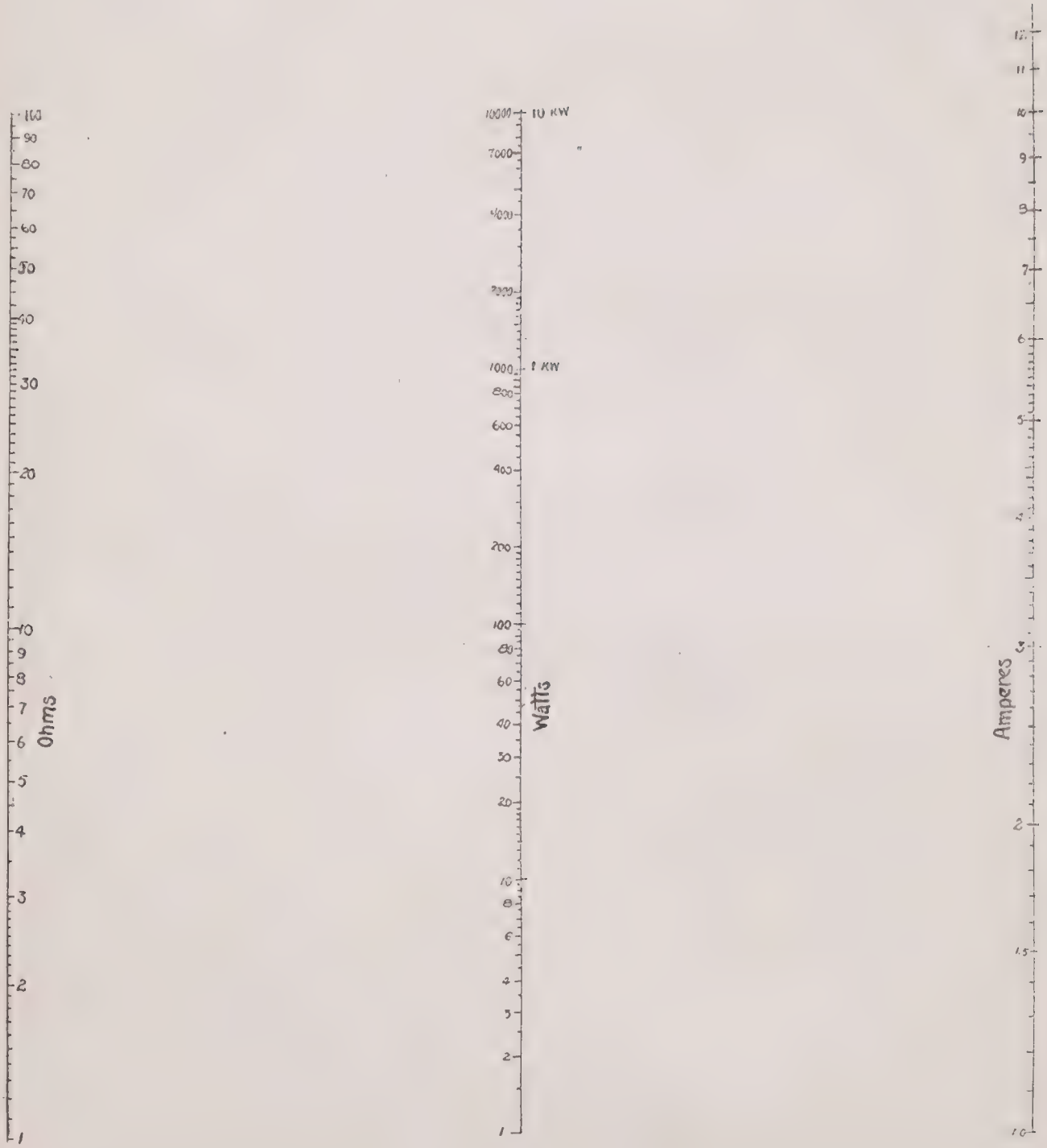
Here, on the scales marked "Logarithm of Number," the graduations are equally spaced. On the opposite side of the line another scale is shown with unequally spaced graduations. The relation between the two scales is such that if any number is chosen from 1 to 10 on the left side of the line, its logarithm may be found directly opposite on the right side of the line. Scale "A" will give the logarithm to the Naperian base (=2.71826) and scale "B" will give the logarithm to the base 10. For the purpose of this book it is not necessary to understand the principles of logarithms, however.

In order to readily locate points on such scales it is desirable to practice locating such points as 1.74, 2.34, 7.5, 9.4, and similar values on these scales, to be able to quickly select a point and to interpolate values between divisions.

The charts provide an easy way to solve with equal facility for any one of the factors that make up the formula. Ordinarily the description accompanying each chart will outline the method for solving one factor, but by reversing the method any other solution may be obtained.

Watts = Resistance × (Amperes)^2

ANY one of these factors may be determined if the other two values are known. For values of resistance over 100 ohms multiply both the resistance and watts scales by 10 or 100, as desired.



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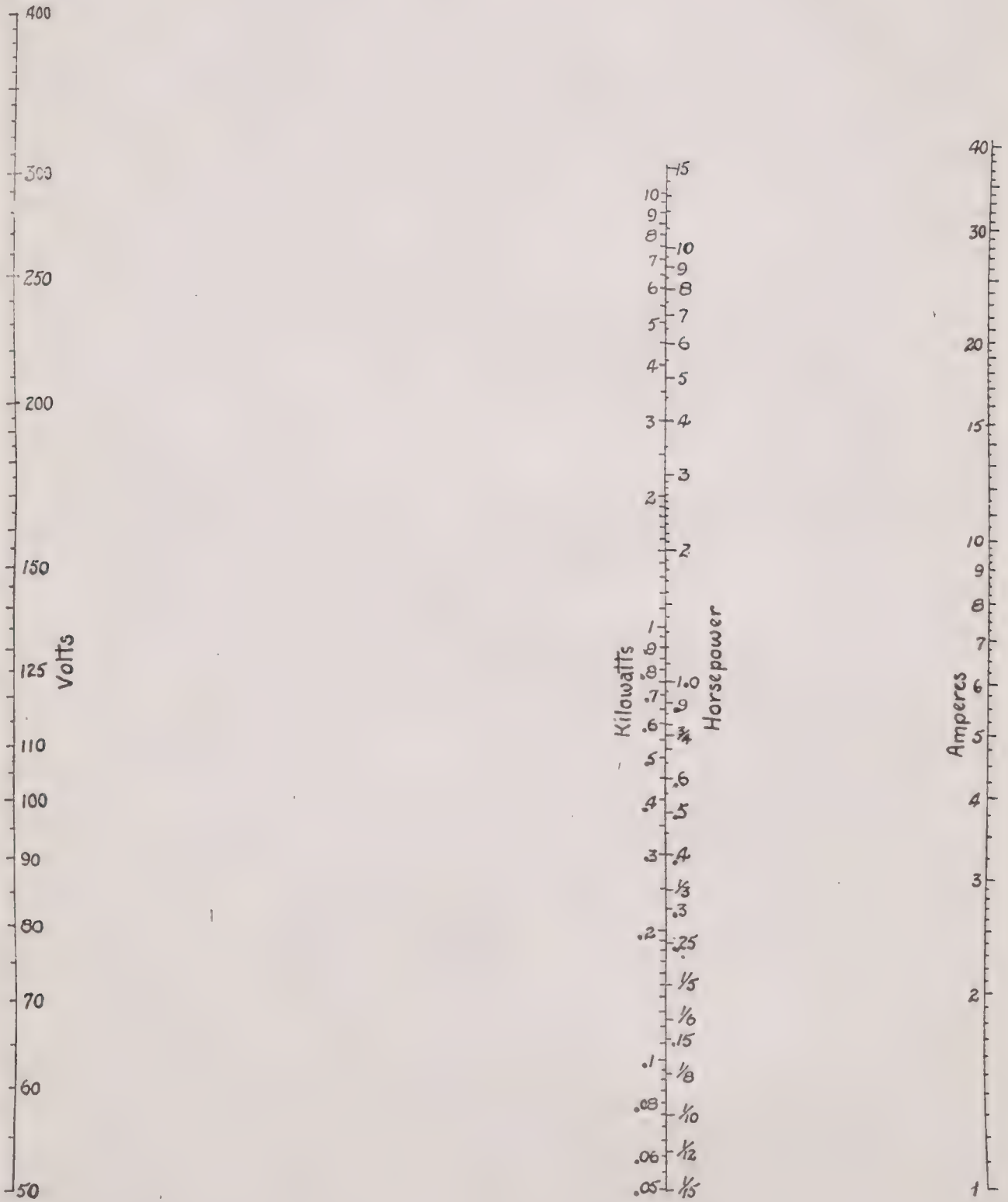
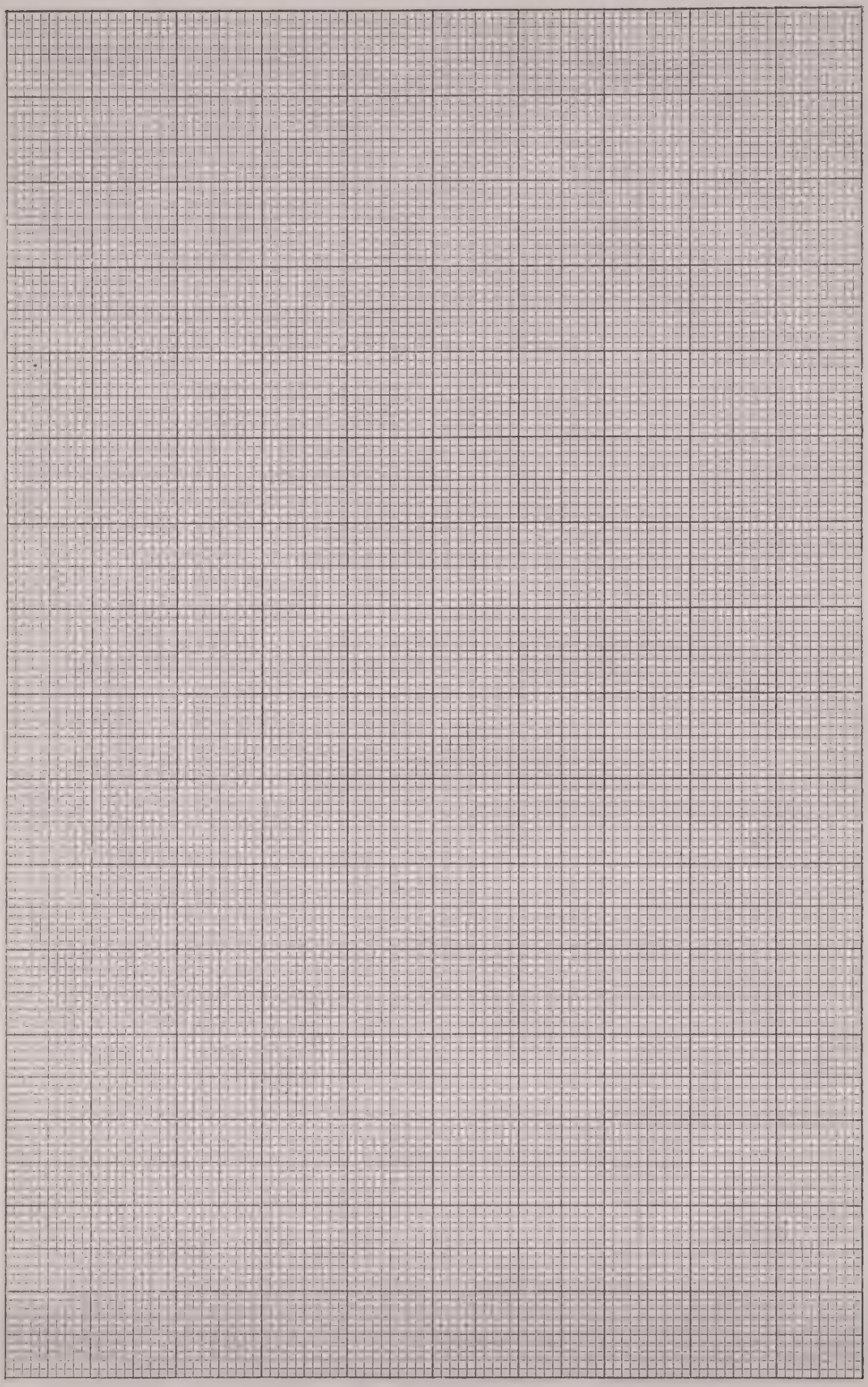
Volts, Amperes, Kilowatts and Horsepower

ANY straight line cutting all three scales will cross those scales at values that will fit the equation

$$\text{Kilowatts} = 1000 \text{ E} \times \text{I} = 1.34 \times \text{Horsepower.}$$





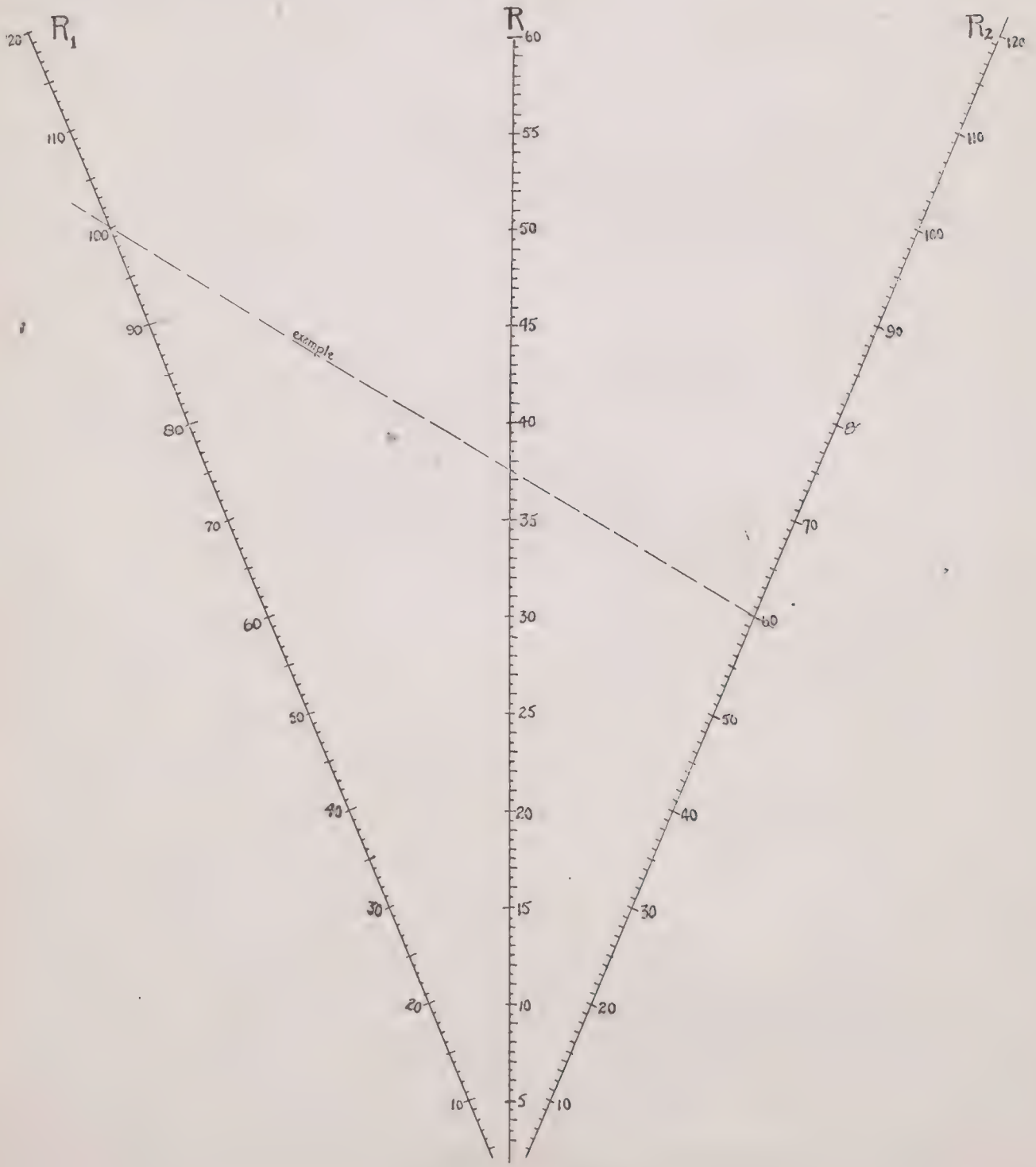
Resistances in Parallel

THE effective resistance of a combination of two resistances in parallel is always less than either resistance taken by itself. The relation is determined by the following formula:

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

where R is the resulting resistance, and R_1 and R_2 are the values of the resistances. All units are measured in ohms. To solve with chart: Locate points on the scales R_1 and R_2 that correspond to values of the resistances that are connected in parallel. Lay the edge of a ruler to correspond with these points. The answer R will be found at the point where the ruler crosses the center scale. For other ranges of resistances multiply all values by 0.01; 0.1; 10. or 100. as desired.

Example: R_1=100 ohms, R_2= 60 ohms, then R=37.5 ohms.

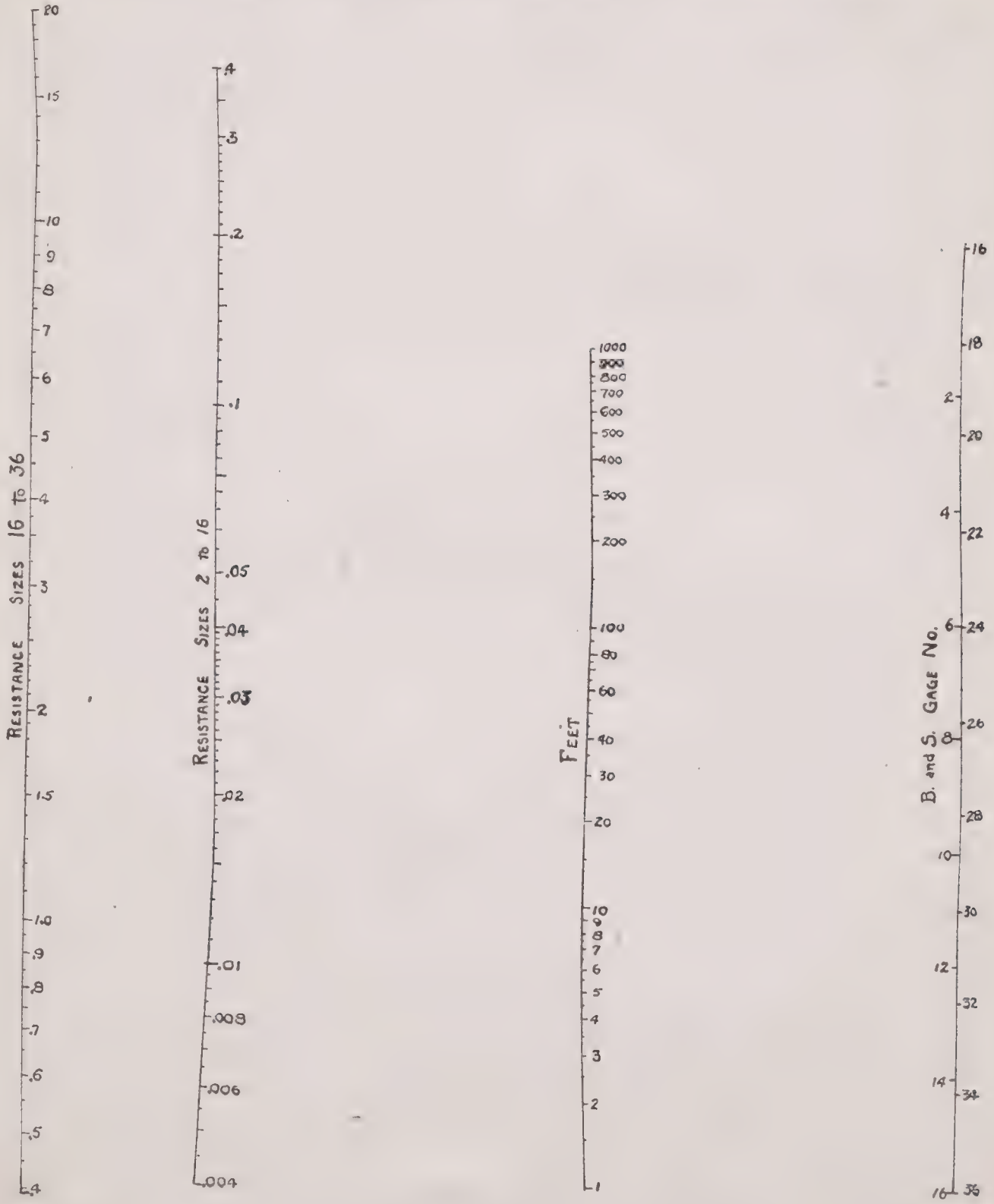


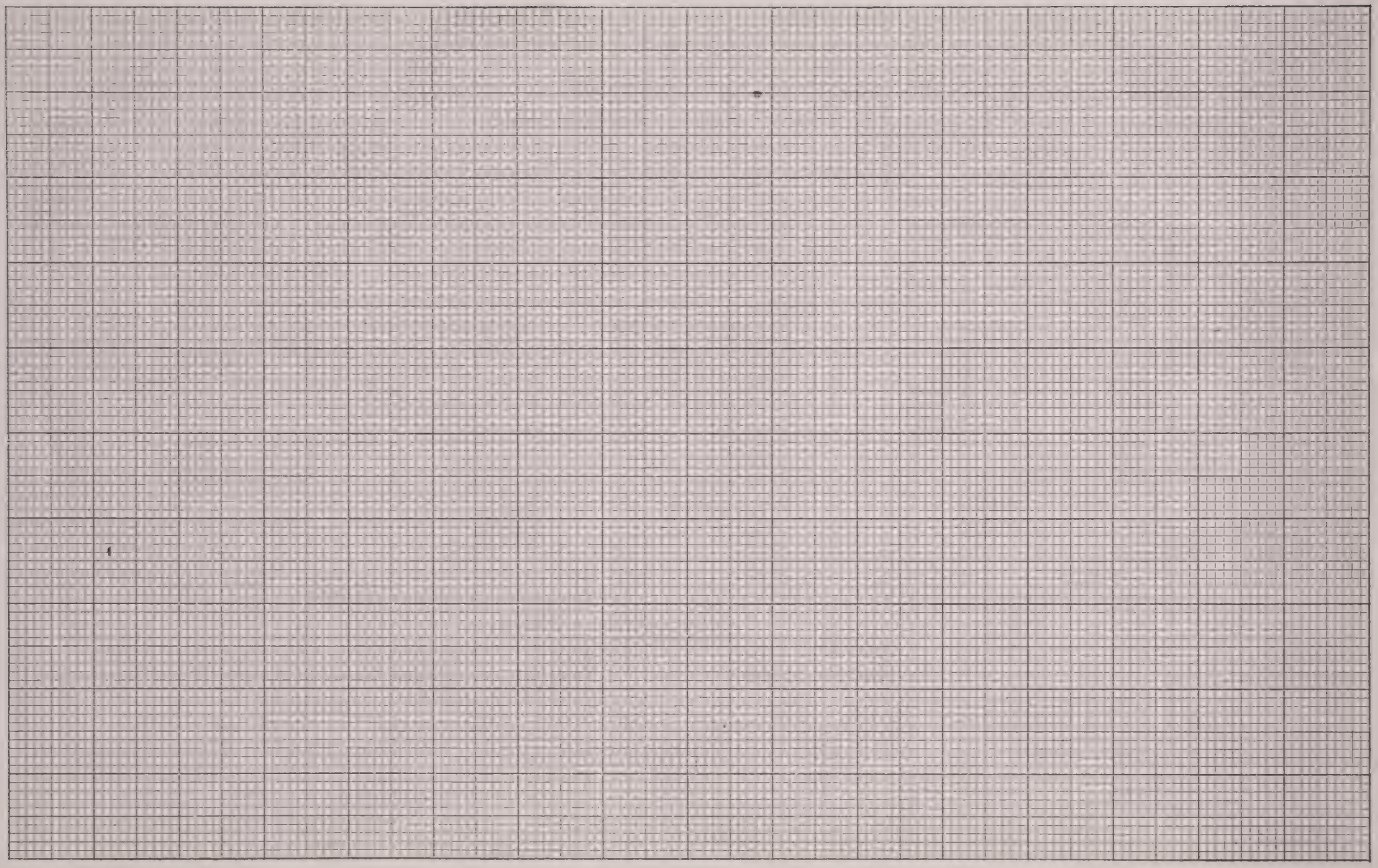
Resistance of Wire

THIS chart will give the resistance of standard wire (at 25° C.) of various lengths. Method: Select the size of wire (No. 2 to No. 36) on scale at right. Select a point corresponding to length desired on center scale. The resistance in ohms will be found on one of the scales at the left of the page (for wire sizes 2 to 16 use scale 2, and for sizes 16 to 36 use scale at extreme left) by extending the line that cuts the other scales at the determined points.

For lengths over 1,000 feet, remember the rule that resistance is proportional to length. The resistance of 5,000 feet is ten times the resistance of 500 feet. This chart is designed for copper wire only.

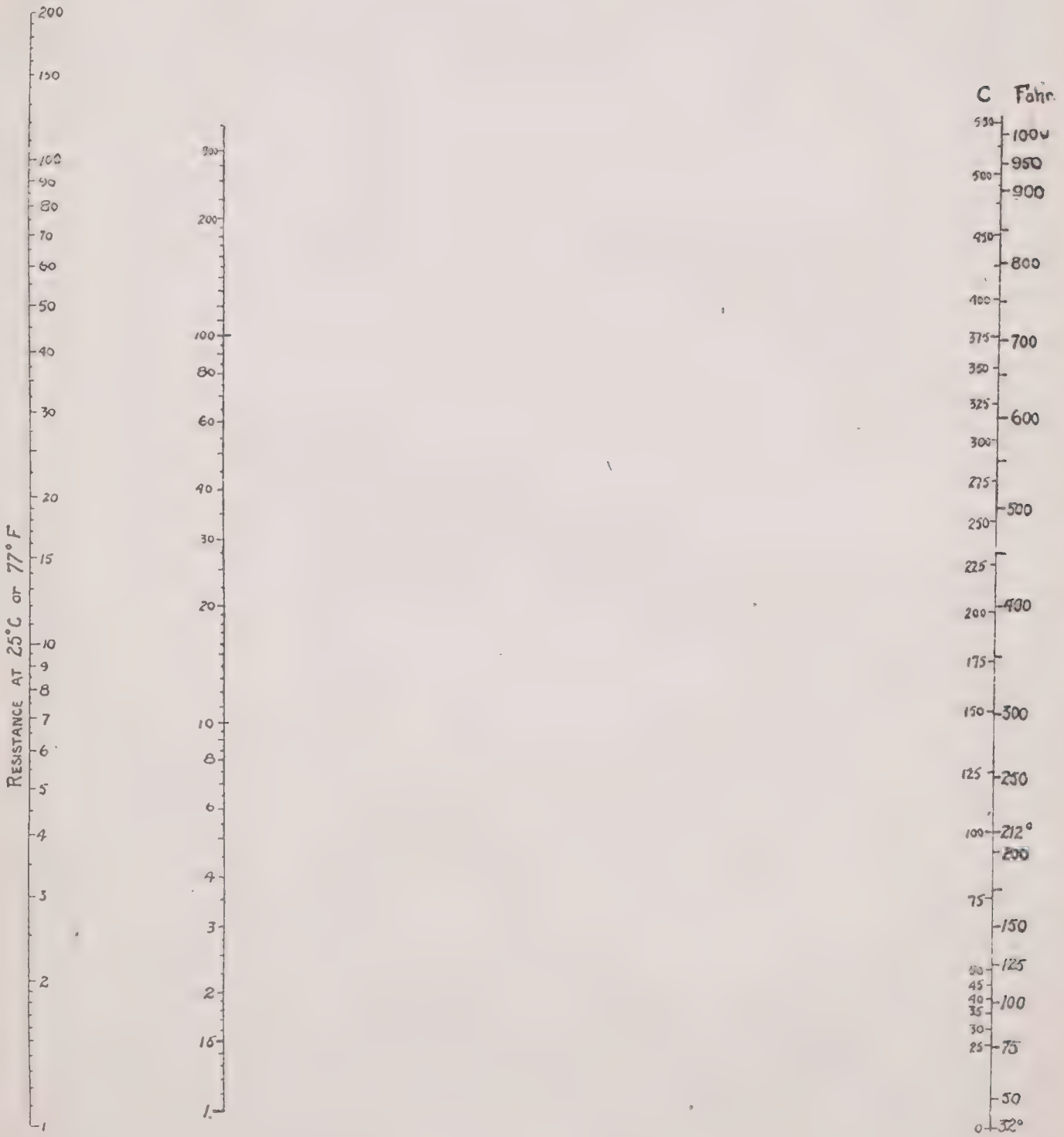
If the answer is found to be above the resistance scale, determine the resistance of a wire 0.1 as long and then multiply that resistance by 10.





Temperature Effect on Resistance

RESISTANCE of copper wire increases with an increase in temperature. The preceding chart will give the resistance of copper wire at ordinary temperature. To change to any other temperature use chart below. The scale at the left represents the temperature at 25° Cent. The scale at the right represents some other temperature. The center scale will give the resistance of the wire at the temperature selected. Determine where a straight line starting from points selected on scales 1 and 3 will cut scale 2. Values can be found on scale 3 for both the Centigrade and Fahrenheit systems.



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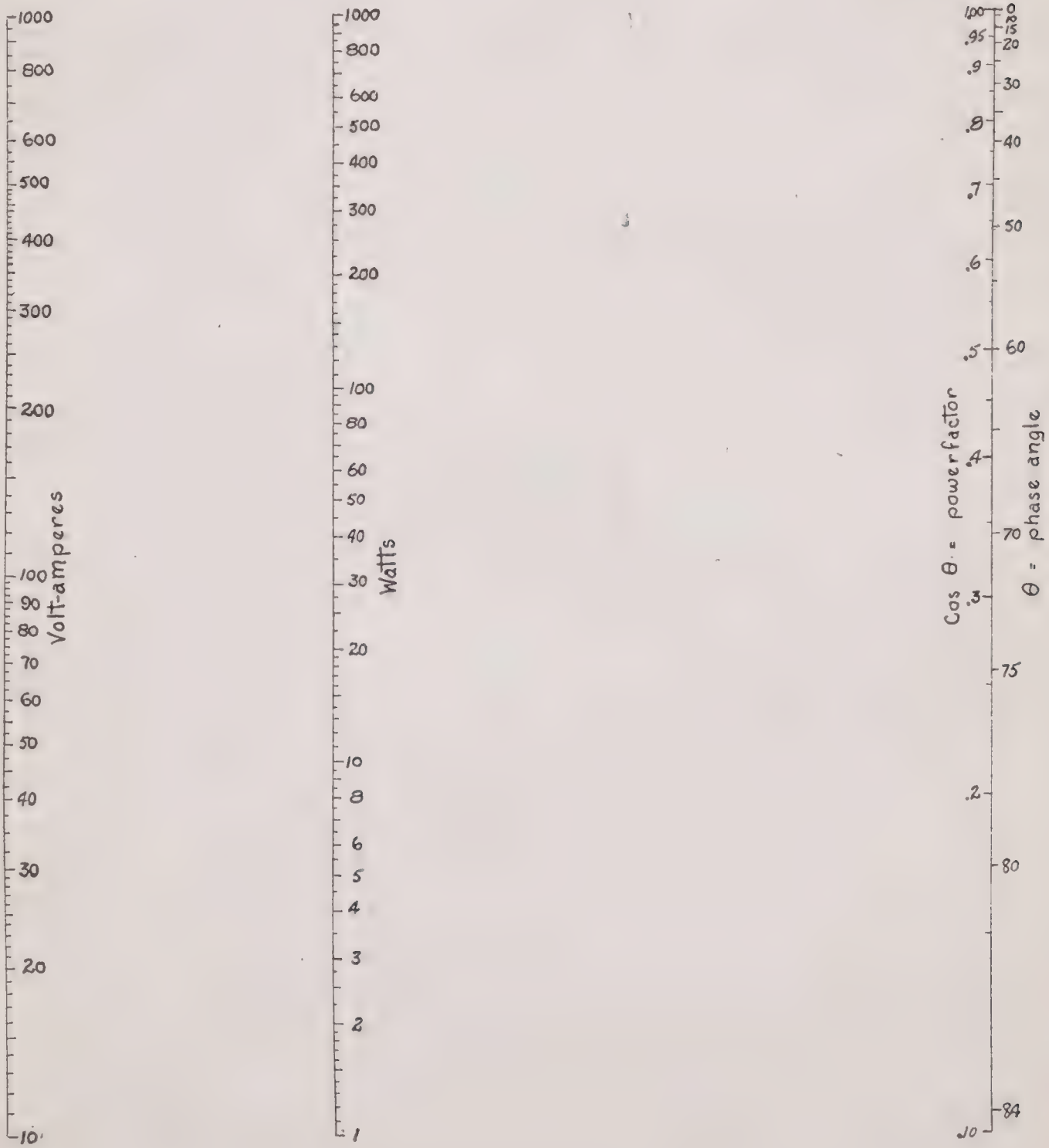
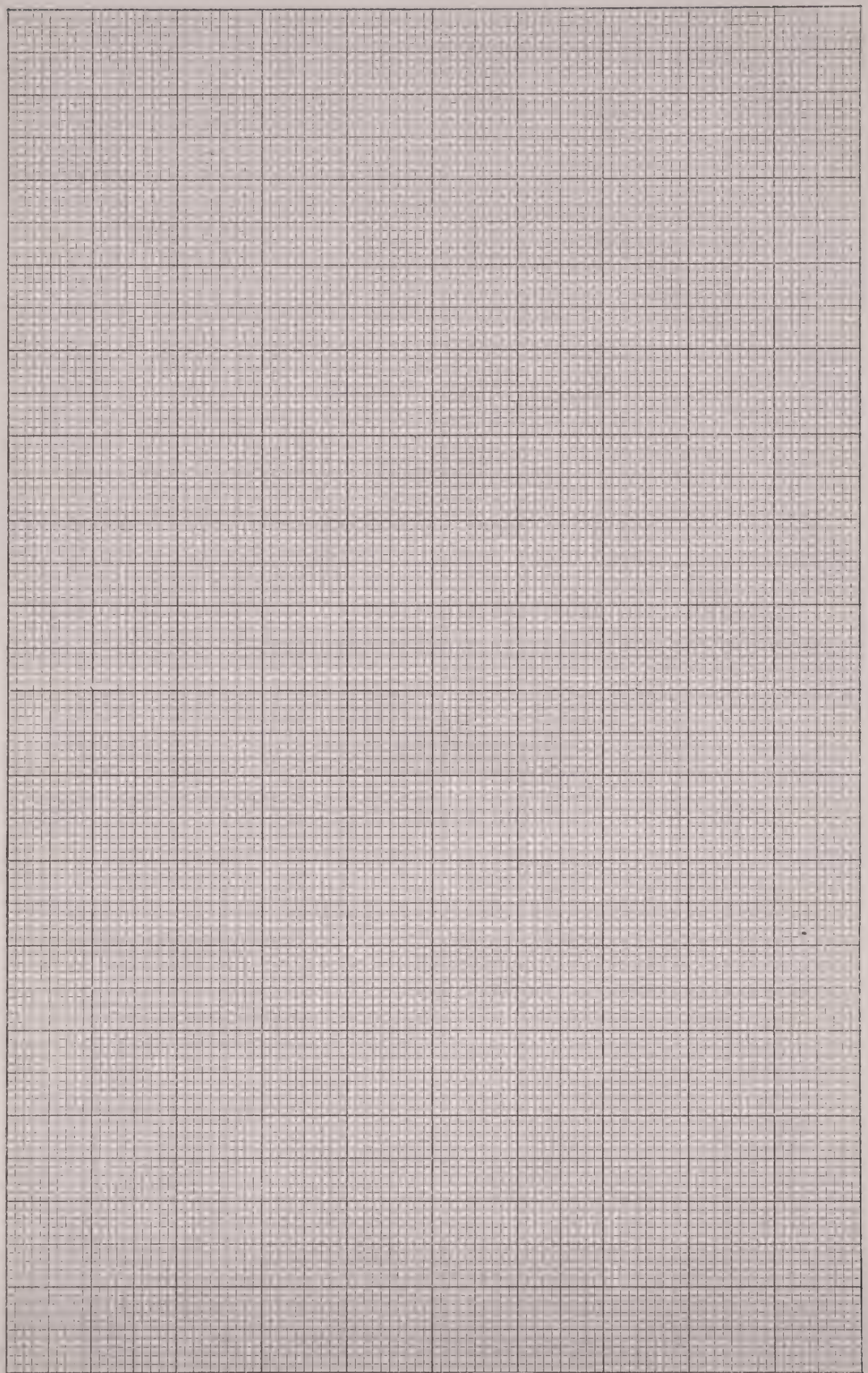
Determining the Power-Factor

A WATT is equal to one volt × one ampere (in alternating currents) only when the voltage and the currents are working together. This occurs when they reach their maximum values at the same instant. However, if one lags behind the other by any angle θ the watts can be calculated by the relation: Watts=E × I × cosine θ. The chart below may be used to solve this equation. Or, if the watts are determined with a wattmeter and the volts and amperes measured with separate instruments, the chart may be used to determine either the powerfactor (the name given to the value of Cos θ) or the powerfactor angle or phase angle as it is sometimes called.

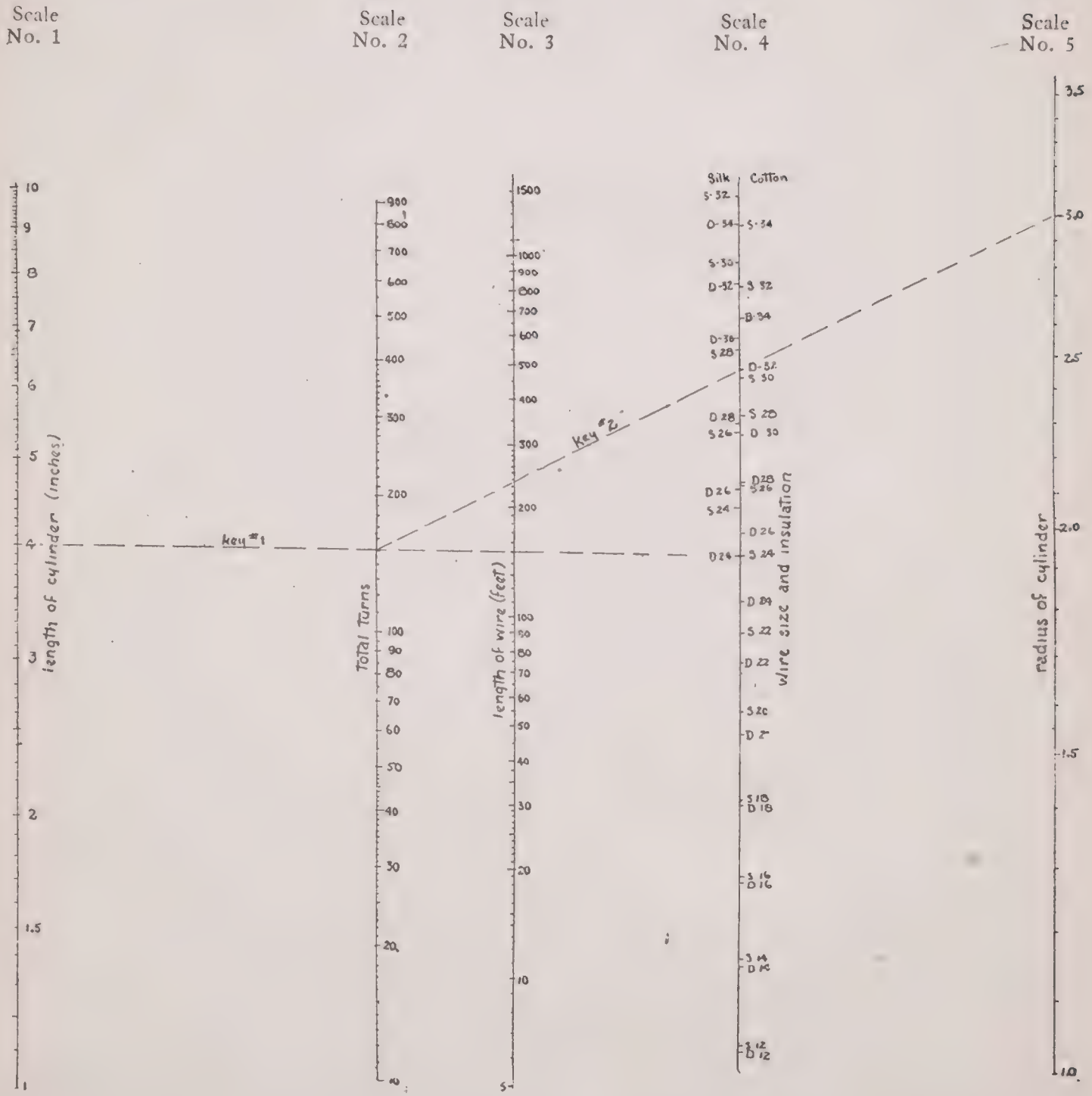




Winding Data—Single Layer Coils

TO simplify the description the scales on this chart will be referred to by numbers starting from left to right: No. 1—length of cylinder in inches. No. 2—total turns. No. 3—length of wire in feet. No. 4—the size of wire and type of insulation. No. 5—radius of tube in inches. On the left side of the line on scale 4 silk insulated wire is referred to; on the right side of the line, cotton insulation. Thus D—30 would indicate double silk covered No. 30 wire if found on the left side, or double cotton covered No. 30 if found on the right side.

Method: To find total number of turns, use scales 1 and 4 and find answer on 2 (see key No. 1 on chart). To find length of wire required take value thus found on scale 2 and run straight line to scale 5. The length of wire in feet is found on scale 3 (see key No. 2).



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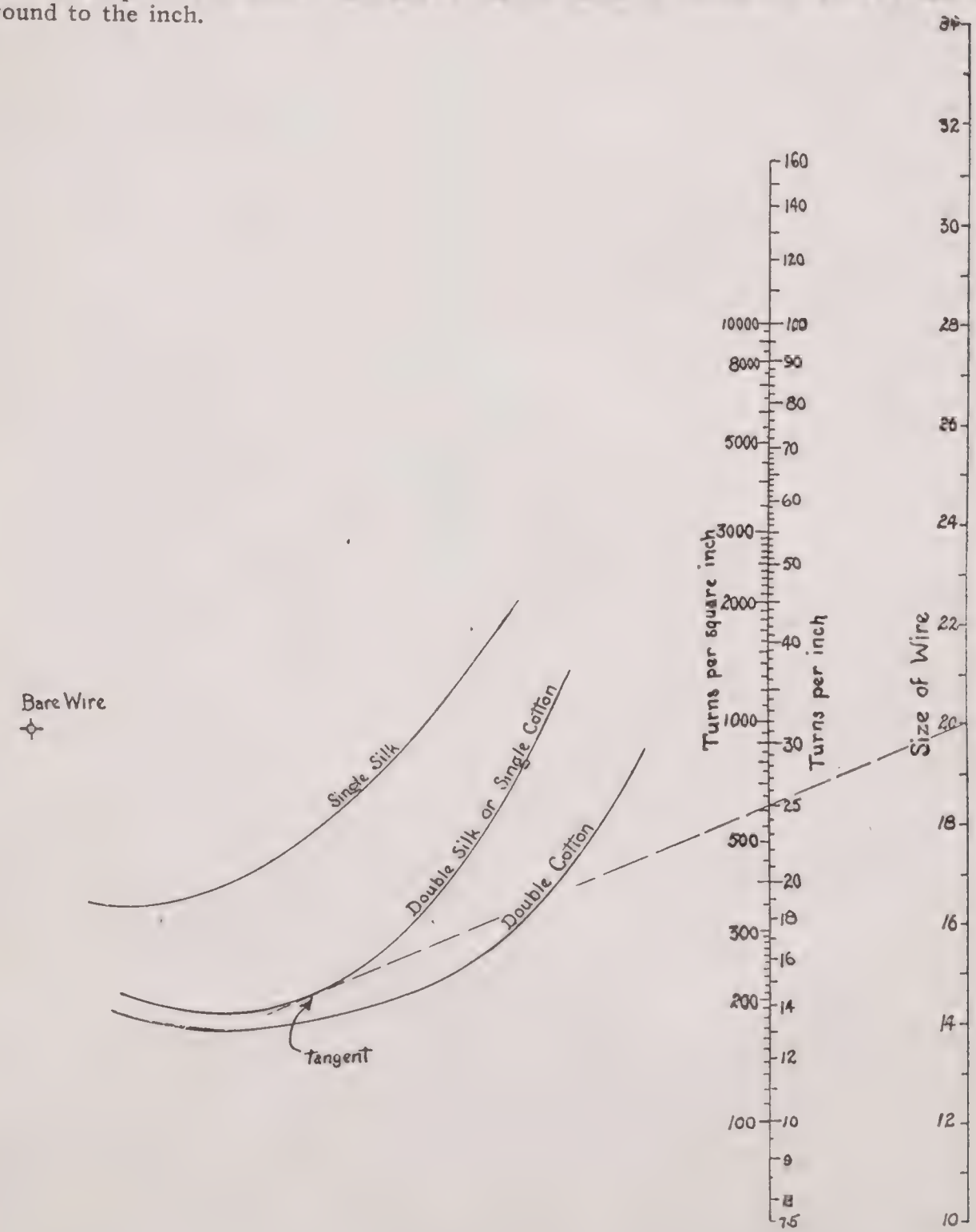
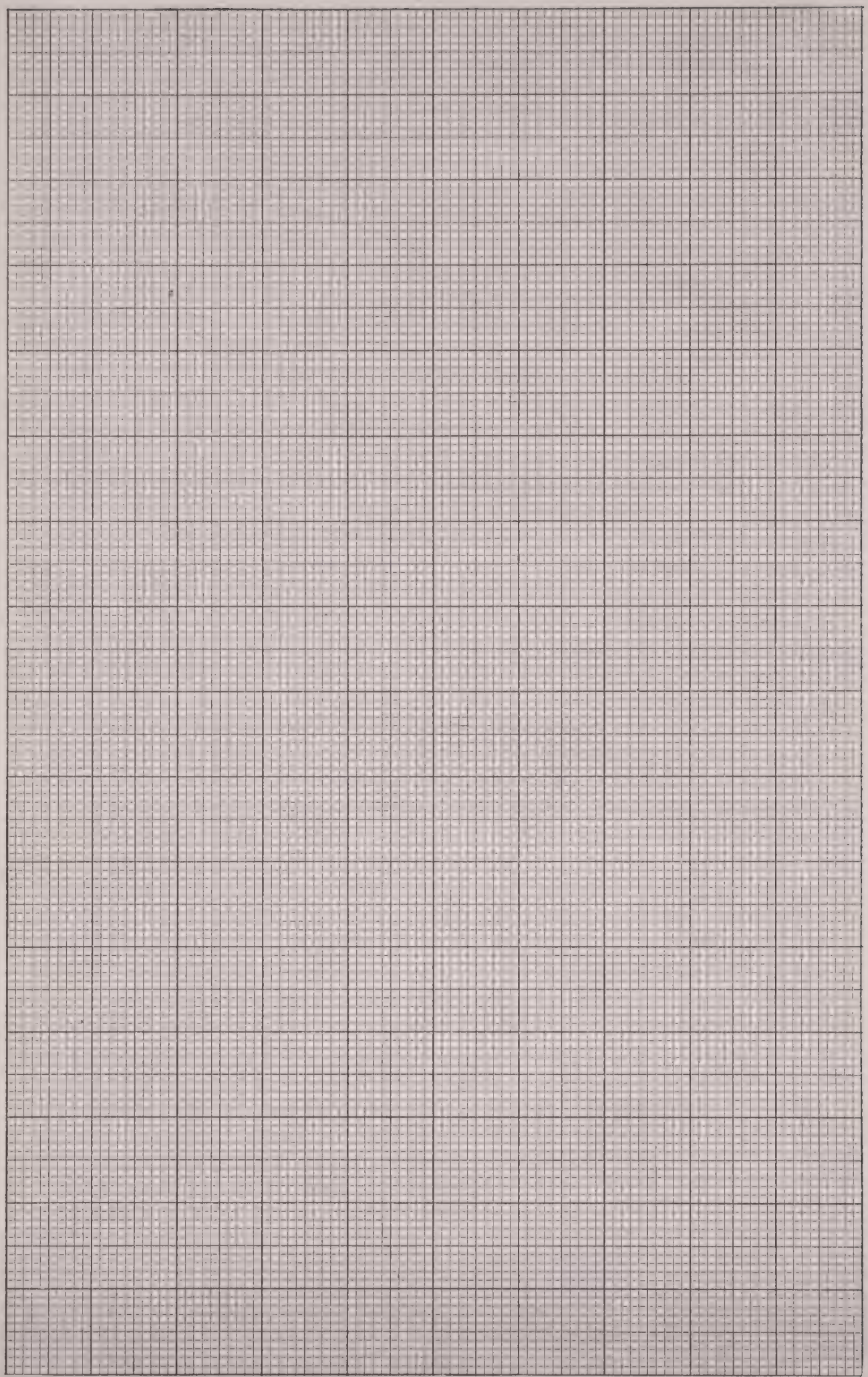
Winding Data—Insulated Magnet Wire

TO determine the number of turns per inch and turns per square inch. This chart is based on average values from several manufacturers. On the scale at the extreme right locate the size of wire under consideration. At the extreme left a single point is located which can be used for close wound bare wire. A straight line between this point and the wire size scale will cut the "turns per inch" scale at a point representing the average turns per inch. The values for "turns per square inch" is located on the opposite side of the line.

When insulated wire is used a line tangent to one of the curves (found near the center of the chart) and cutting the scale at the right at the desired wire size will determine the turns per inch or turns per square inch of the wire, including the insulation. Three curves are given: the upper one for Single Silk covered wire, the middle one for Double Silk covered or Single Cotton covered, and the lower one for Double Cotton covered.

Example: The dotted line shows that 25 turns of S.C.C. No. 20 wire can be wound to the inch.

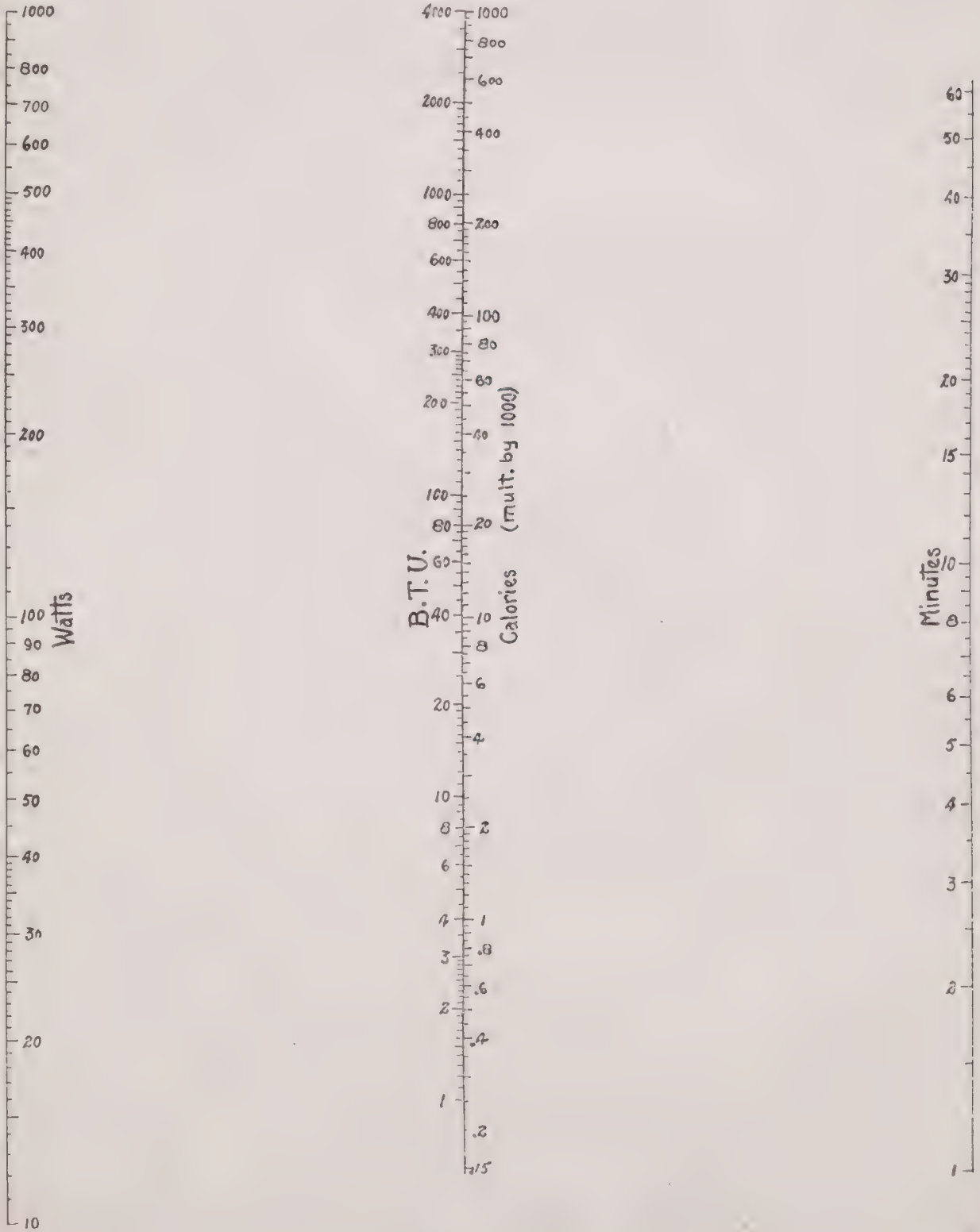




Heat from Electrical Circuit

TO determine the amount of heat given from an electrical device use the chart below. Scale 1 is graduated in Watts with a range of 10 to 1000. Graduations on the third scale correspond to the number of minutes that the device is used. The resulting heat given off during this interval is found on the center scale, the value being read at the point where a straight line (terminating at points representing the number of watts and minutes) intersects the middle scale. The answer can be read in either British thermal units, or gram calories. The value for calories must be multiplied by 1000.

A calorie will raise the temperature of one gram of water one degree Centigrade.
A B.T.U. will raise the temperature of one pound of water one degree Fahr.



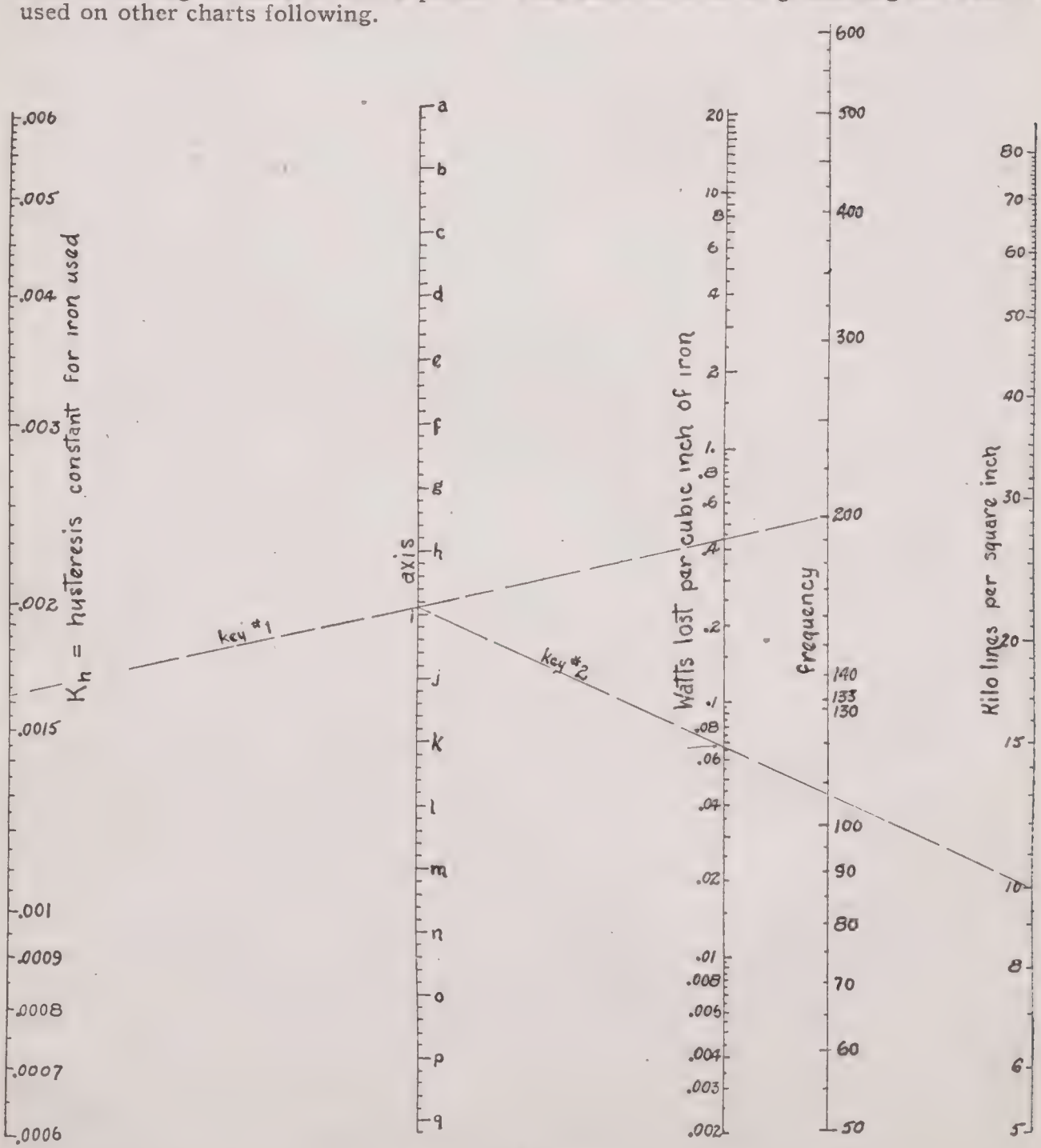
Hysteresis Loss in Iron

IT requires a certain amount of energy to build up a field in an iron core. The amount of energy required depends upon the grade of iron used, the amount of iron and the final strength of the field. If the field is an alternating one, this energy loss is continuous and increases as the frequency increases.

To determine the amount of power expended per cubic inch of iron in the magnetic path use the following chart. Here K_h denotes the hysteresis constant for the type of iron used. The value of this factor can be obtained from the manufacturer of the core iron. For ordinary transformer iron it has a value about .002, but the value decreases to about .0009 for silicon steels.

Method: Determine where a line from the K_h scale to the frequency scale cuts the axis (key No. 1). From this point of intersection determine where a line to the flux density scale at the extreme right will intersect with the loss scale (key No. 2), at which point the watts lost per cubic inch of core may be read directly. The density is to be used in the unit—kilolines per square inch of cross sectional area of core.

Example shown: K_h=.001625; frequency=200 cycles; flux density=10,000 lines per square inch. The loss thus indicated is .067 watts per cu. inch of core. The "axis" line is graduated and the divisions are designated by letters. These letters have no significance and are used only to assist in remembering a certain point on the axis without having to mark it with a pencil. This same method of graduating the axis is used on other charts following.



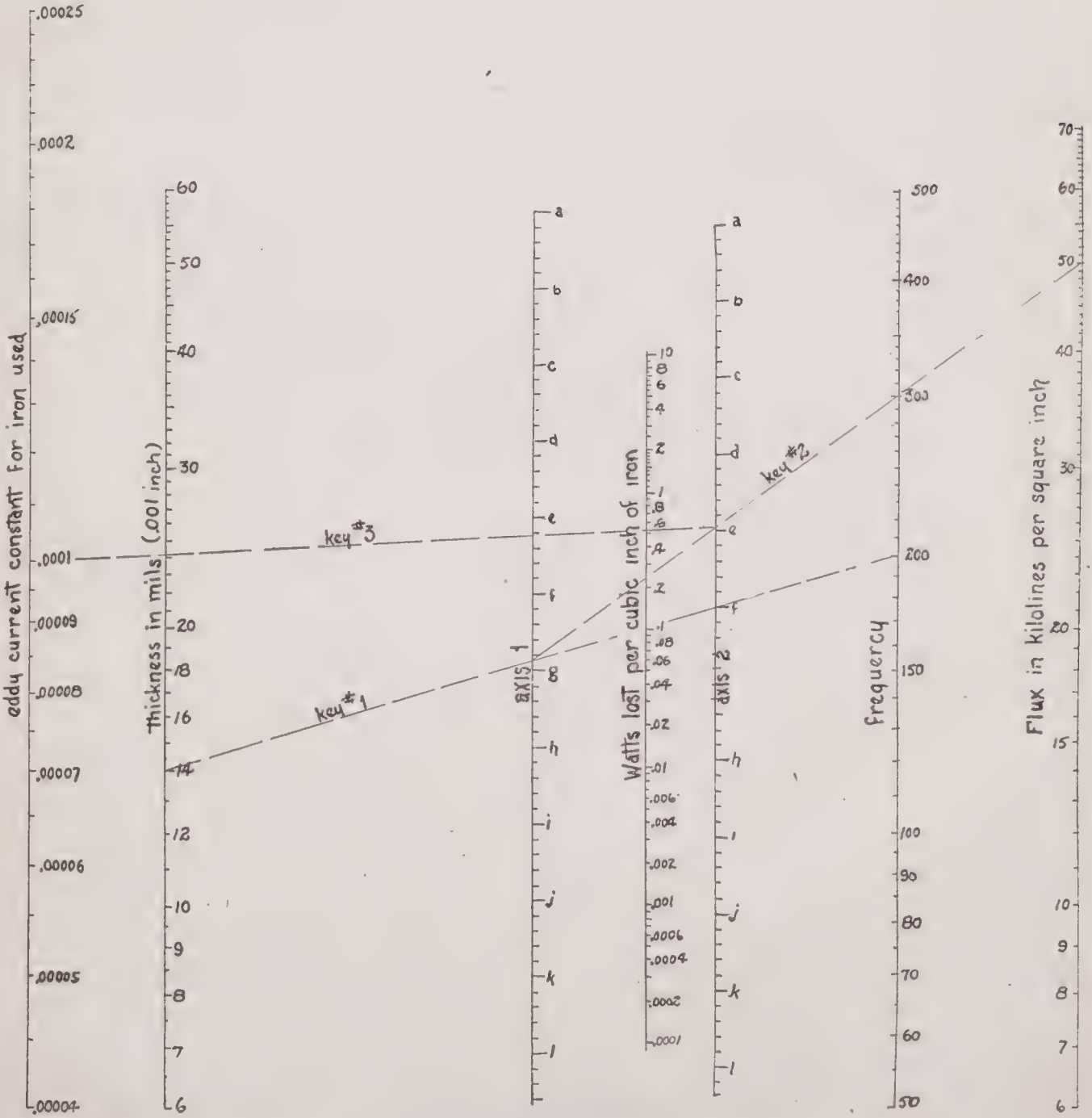
Eddy Current Loss in Iron Cores

THIS loss is due to electrical currents being induced in the iron core by the alternating flux. Find where a line from scale 2 (indicating the thickness of the laminations in thousandths of an inch) to scale 4 (frequency) will intersect Axis 1. From this intersection draw line to scale 5 (flux density) and determine where the line intersects Axis 2. From this point indicate line to scale 1 (eddy current constant for iron used—to be obtained from handbook or from manufacturer). This latter line will intersect the "watts loss" scale at a point indicating directly the loss per cubic inch of core. To find total loss multiply this result by the volume of core in cubic inches.

The constant Ke depends largely upon the electrical conductivity of the material in the core.

Example shown: Thickness of laminations=.014 inch each; frequency=200 cycles; flux density=50,000 lines per square inch; Ke=.0001. Indicated answer=.52 watts loss per cubic inch of core. This value would be multiplied by the volume of core to find total loss.

Scale No. 1 | Scale No. 2 | Scale No. 3 | Scale No. 4 | Scale No. 5

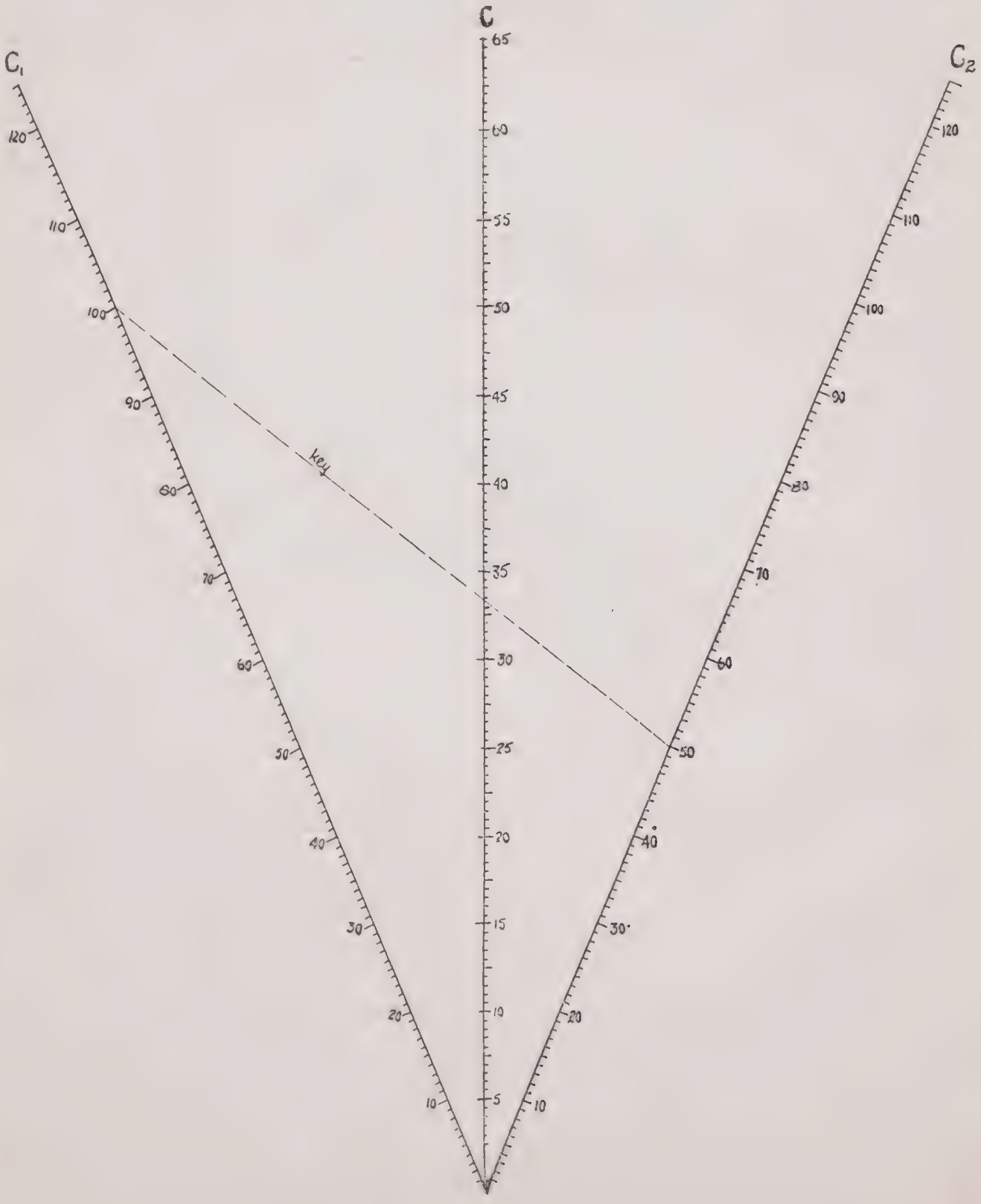


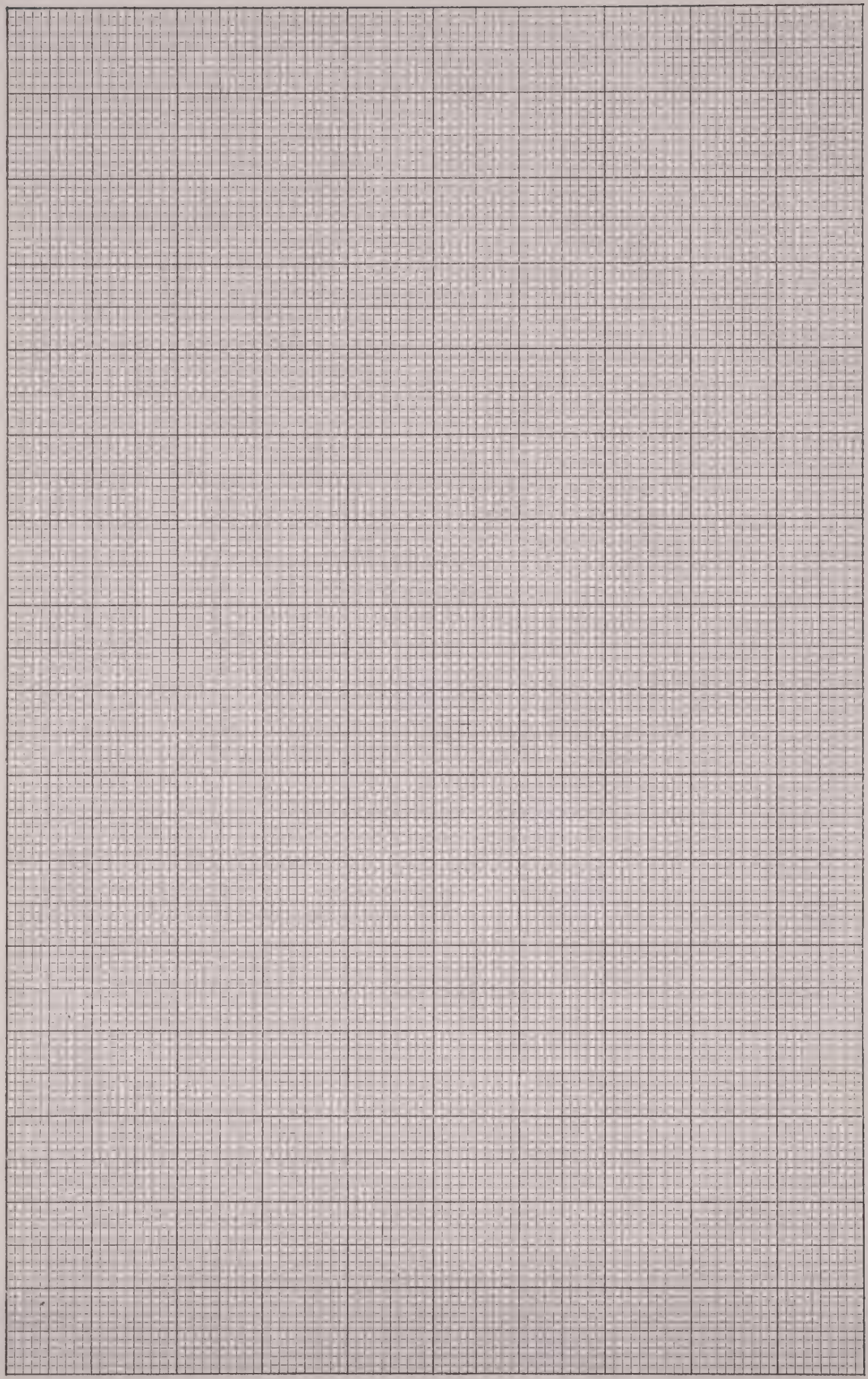
Condensers in Series

THE effective capacity of two condensers in series is always less than that of either of the condensers taken alone. On the following chart the scales are graduated with no particular unit. Thus the unit 20 may stand for 2 microfarads, .002 m.f. or .00002 m.f., as the case demands, but it is essential that the value is interpreted as the same unit on all three scales.

C_1 and C_2 represent the capacities of each of the condensers respectively and C (on center scale) the effective or combined capacity. The chart is used in the same manner as previous charts, as the fact that the scales are not parallel need not be considered.

Example shown by key: If a condenser of 1 microfarad is connected in series with a condenser of 0.5 m.f. the total capacity is 0.33 m.f.



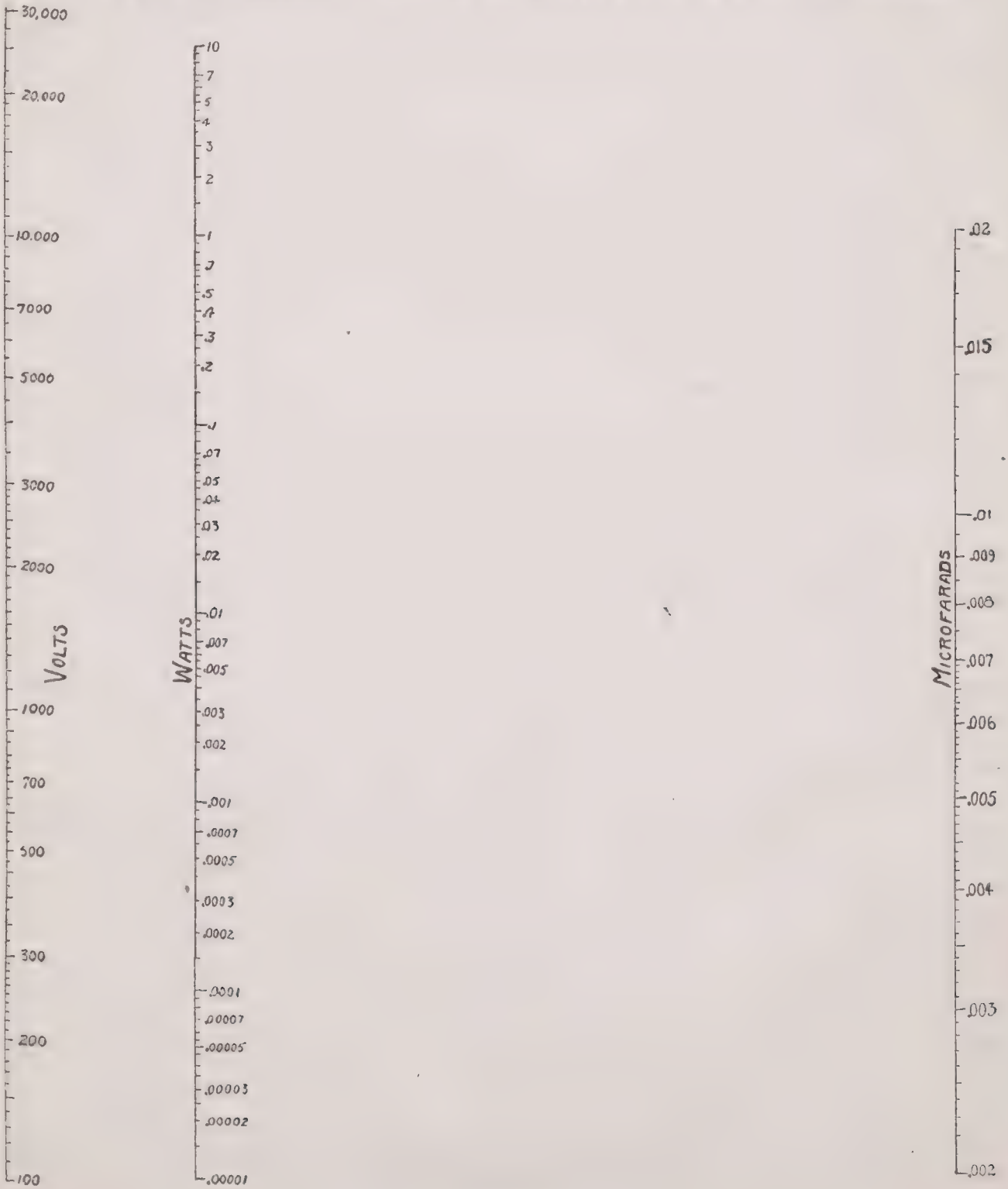


Ability of a Condenser to Store Electrical Energy

A CONDENSER can store electrical energy of an amount depending upon the size of the condenser and the voltage applied. On scales (left) and (right) the charging voltage and microfarads are respectively located, and a line between these points will cut the "Watts" scale at a point that will indicate the number of watts that may be stored up per charge.

In radio work, especially in transmitting equipment, the condenser is alternately charged and discharged a number of times a second, so to determine the rating of a condenser at a particular frequency multiply the watts (as determined by the chart) by twice the frequency. The result will be the number of watt-seconds associated with the condenser during that interval.

For larger condensers than given on the scale the values on the "Microfarads" and the 'Watts" scales should both be multiplied by 10 or 100. Thus: the energy stored on a 2 m.f. condenser is 100 times the energy stored on a .02 m.f. condenser.



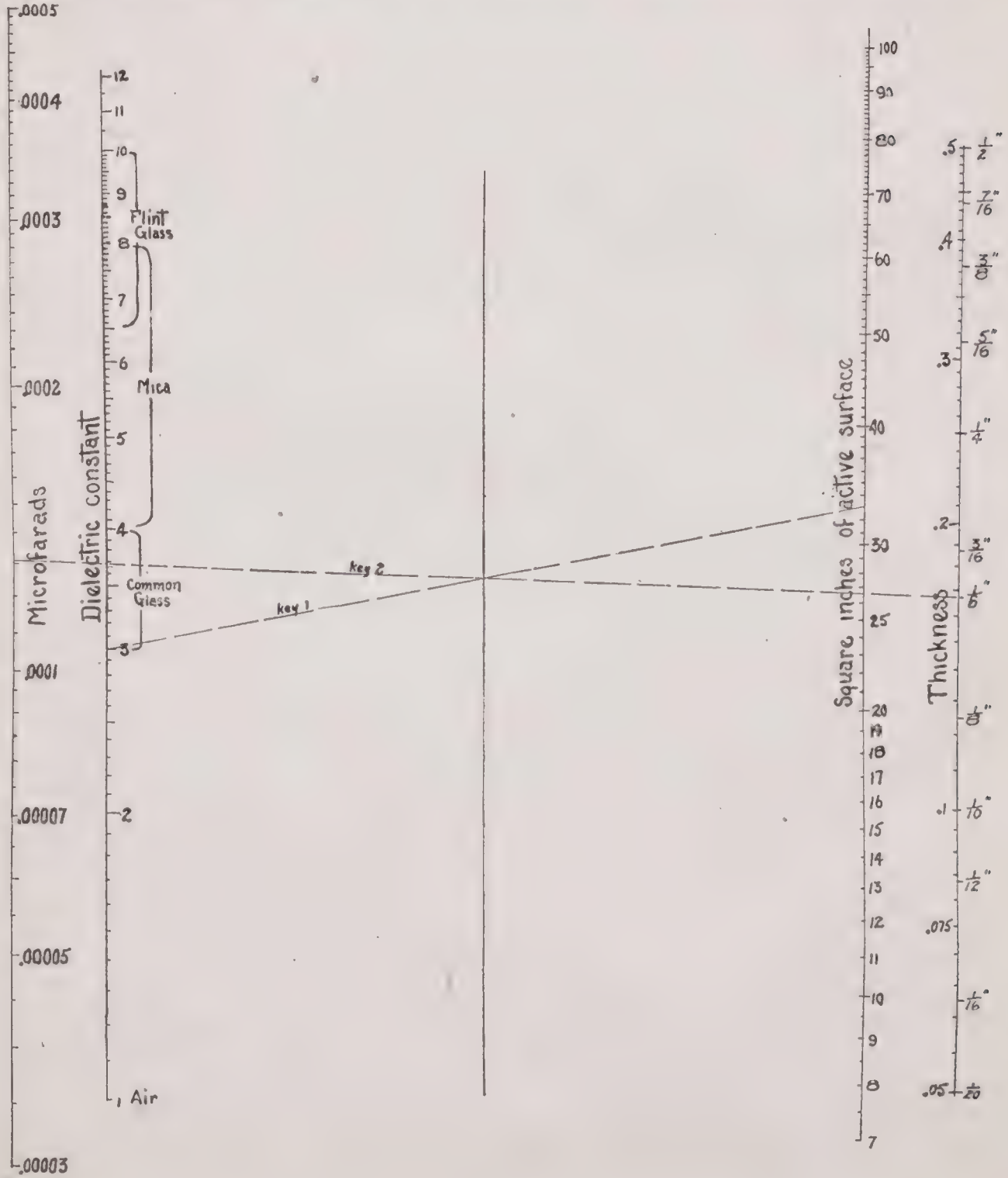
Capacity of a Flat Plate Condenser

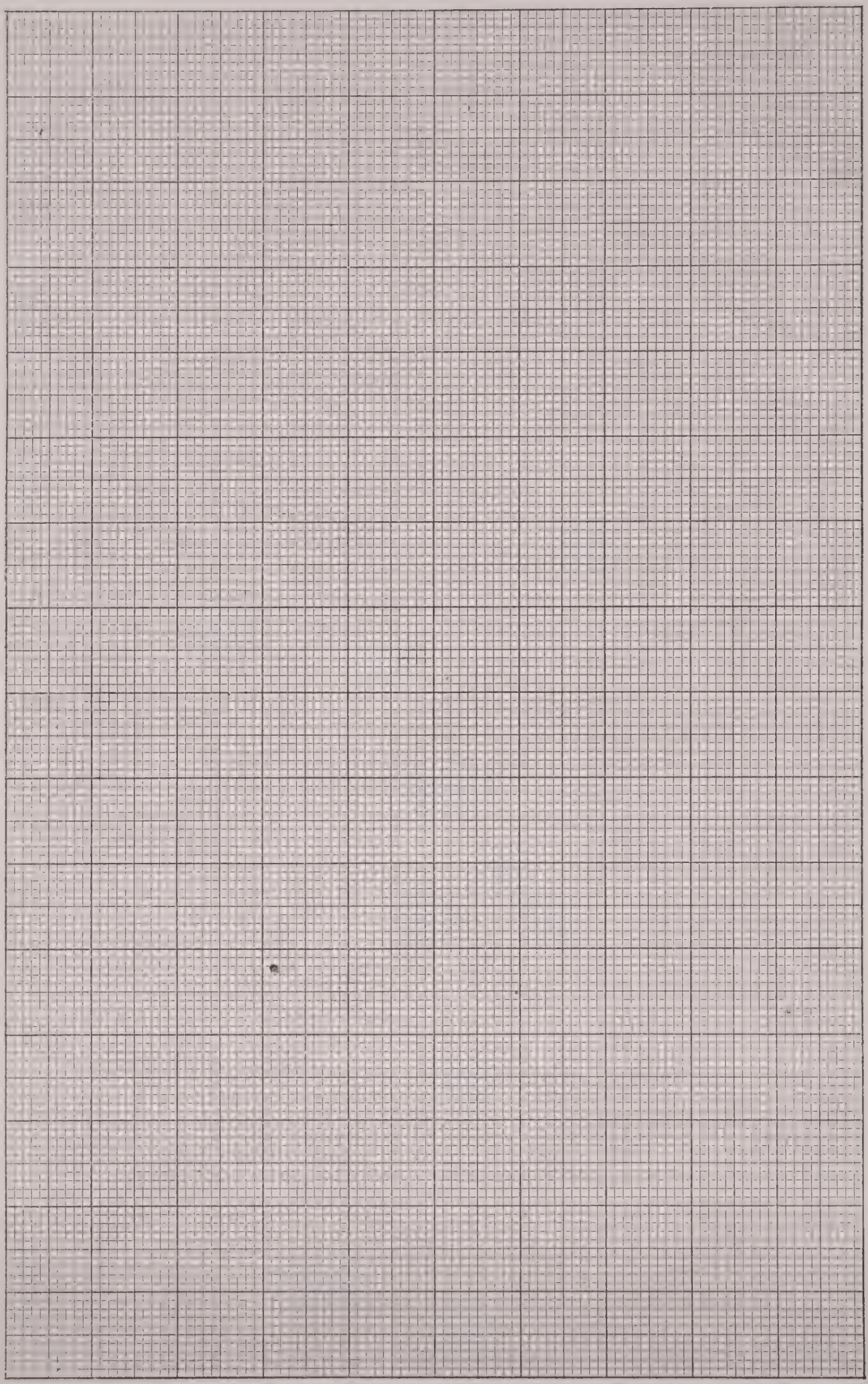
TO find the capacity of a given condenser: Find the point on the center axis where a line between points on the "Dielectric Constant" scale and the "Area" scale will intersect with it. Using this same point on the center axis, draw a line to the "Thickness" scale, extending it till it intersects with the "Microfarads" scale. At this intersection the capacity may be read directly. Referring to the example shown this would mean: First construct a line as Key 1. Then Key 2, so that both Keys intersect on the same point on the center axis.

To find the area required (given the dielectric and distance between plates) construct Key 2 first and then Key 1.

The area given refers to the area of the glass (one side only) between the conducting surfaces. The area and the thickness are both measured in inches.

For condensers using mica insulation divide values on "Thickness" scale by 10 or 100 and multiply capacity values on "Microfarads" scale by same factor, using chart in same way as described above.

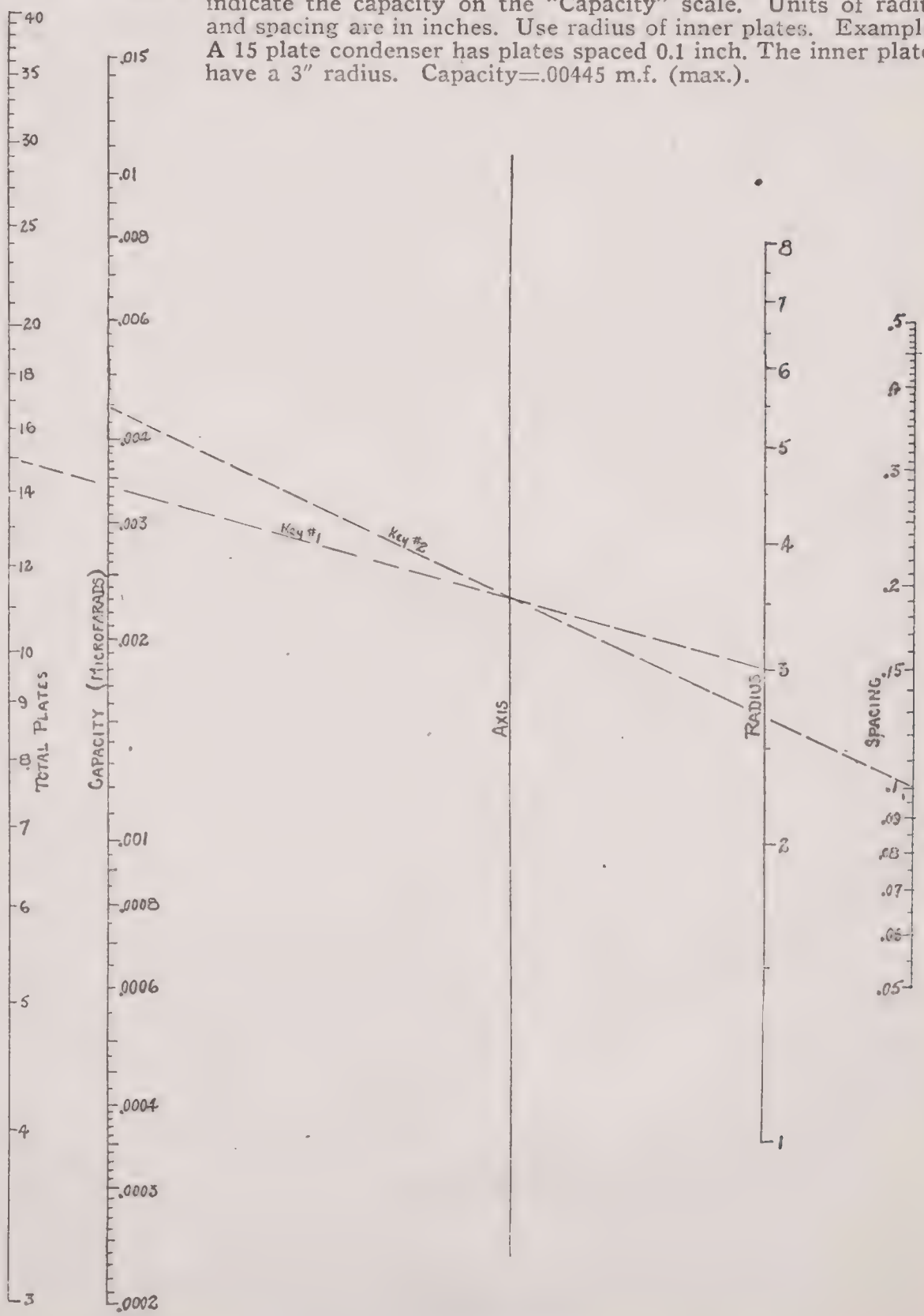




Capacity of a Variable Condenser (Air Dielectric)

THIS chart may be used to determine the maximum capacity of a variable condenser of the semi-circular plate type. The following assumptions have been made: The effect of the hole in the center of the fixed plate is negligible; and the edge effect and the effect of central shaft and container is negligible. These factors produce opposite effects on the capacity so that both may be omitted without serious error.

To use chart, determine point on axis (see key 1) where it is intersected by a line terminating at the "Total Plates" and "Radius" scales. A second line so located that it will terminate at the "Spacing" scale, and intersect the axis and Key 1, will indicate the capacity on the "Capacity" scale. Units of radius and spacing are in inches. Use radius of inner plates. Example: A 15 plate condenser has plates spaced 0.1 inch. The inner plates have a 3" radius. Capacity=.00445 m.f. (max.).



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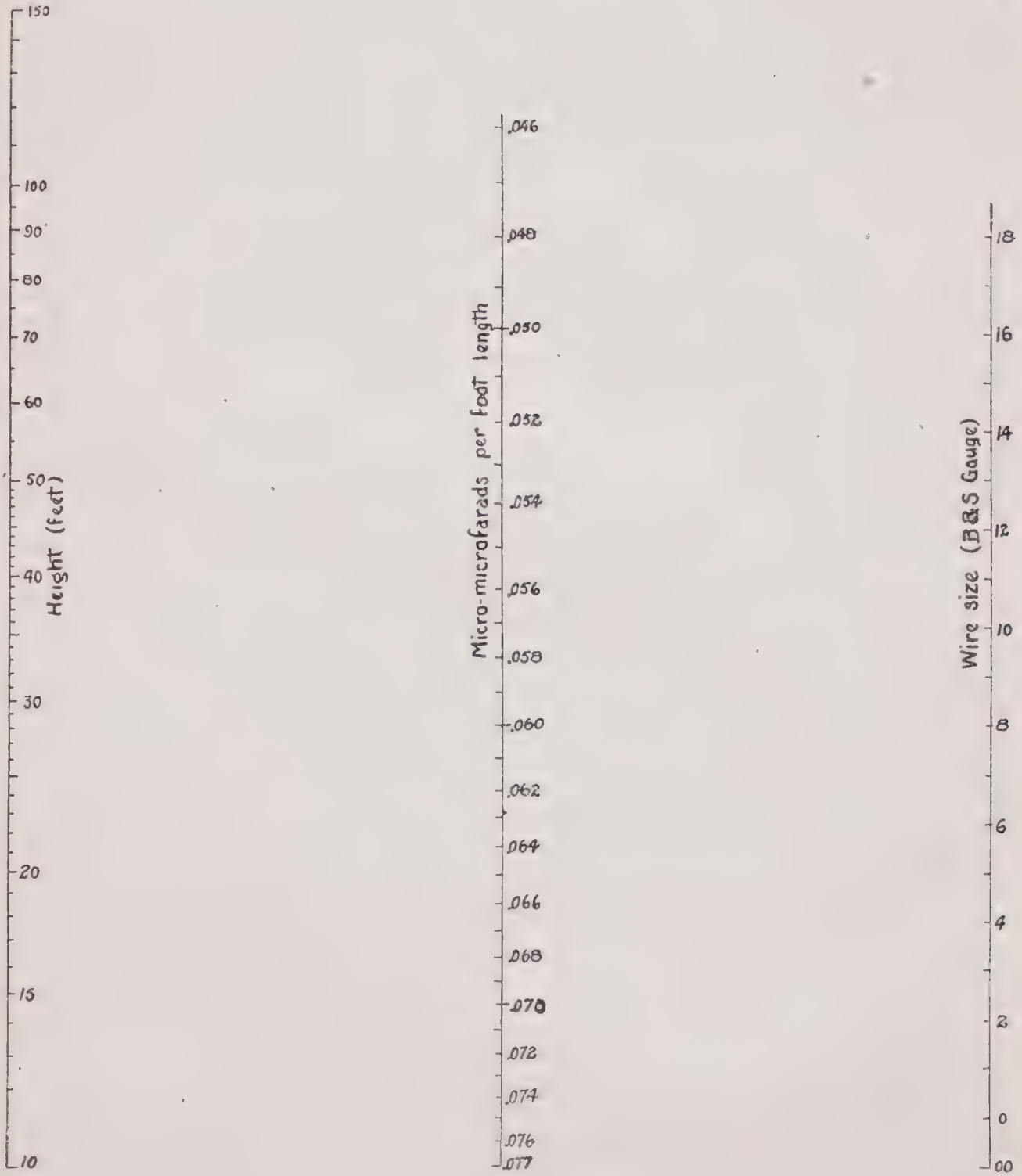
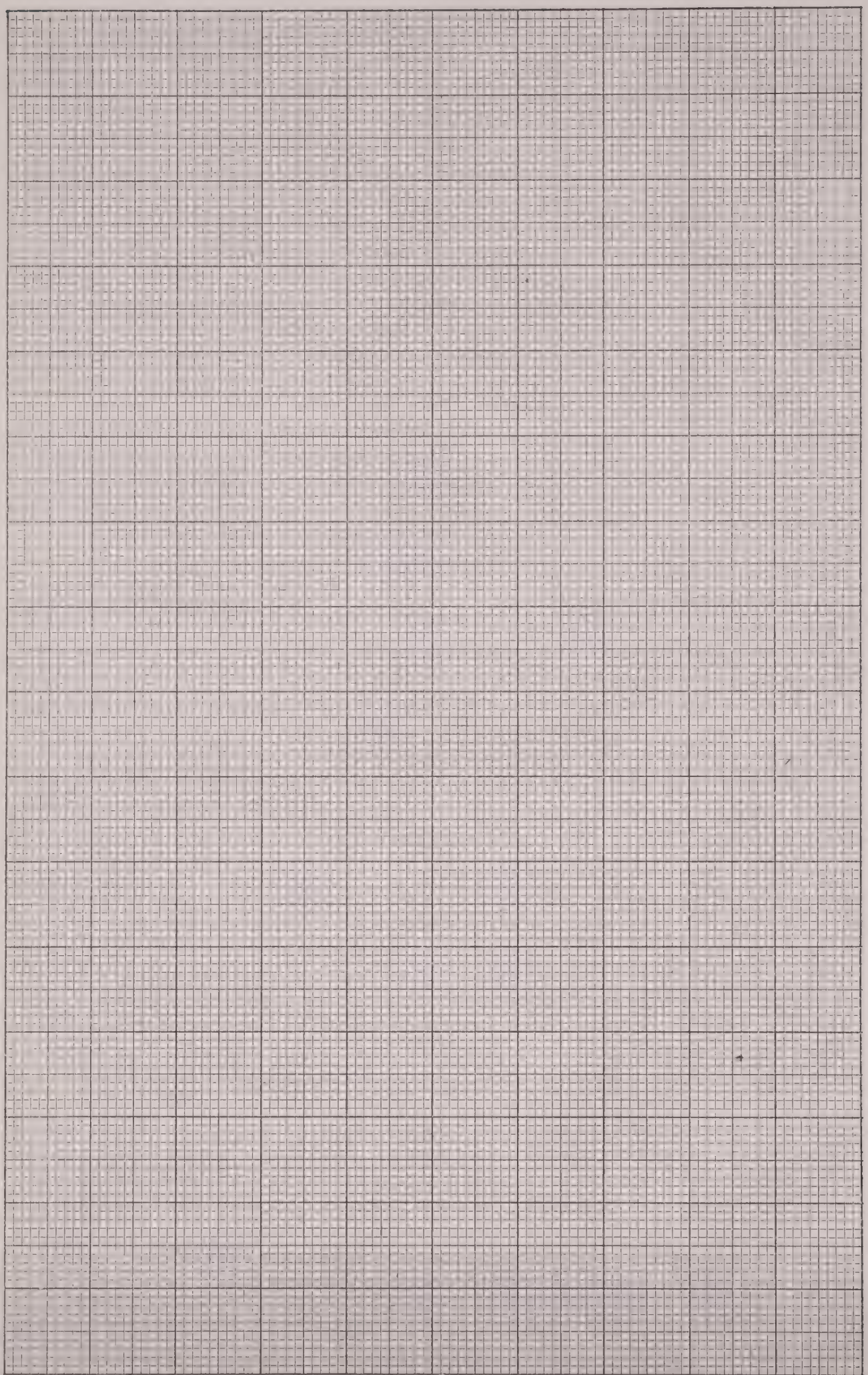
Capacity of an Elevated Wire Horizontal to Earth

THE capacity of an elevated wire depends upon its diameter, its length and its height. The following chart will indicate the capacity per foot of length, of wires from sizes 00 to 18 (Brown and Sharp Gauge), at various heights from 10 feet to 150 feet. The capacity is given in micro-microfarads. To find total capacity multiply by the length in feet.





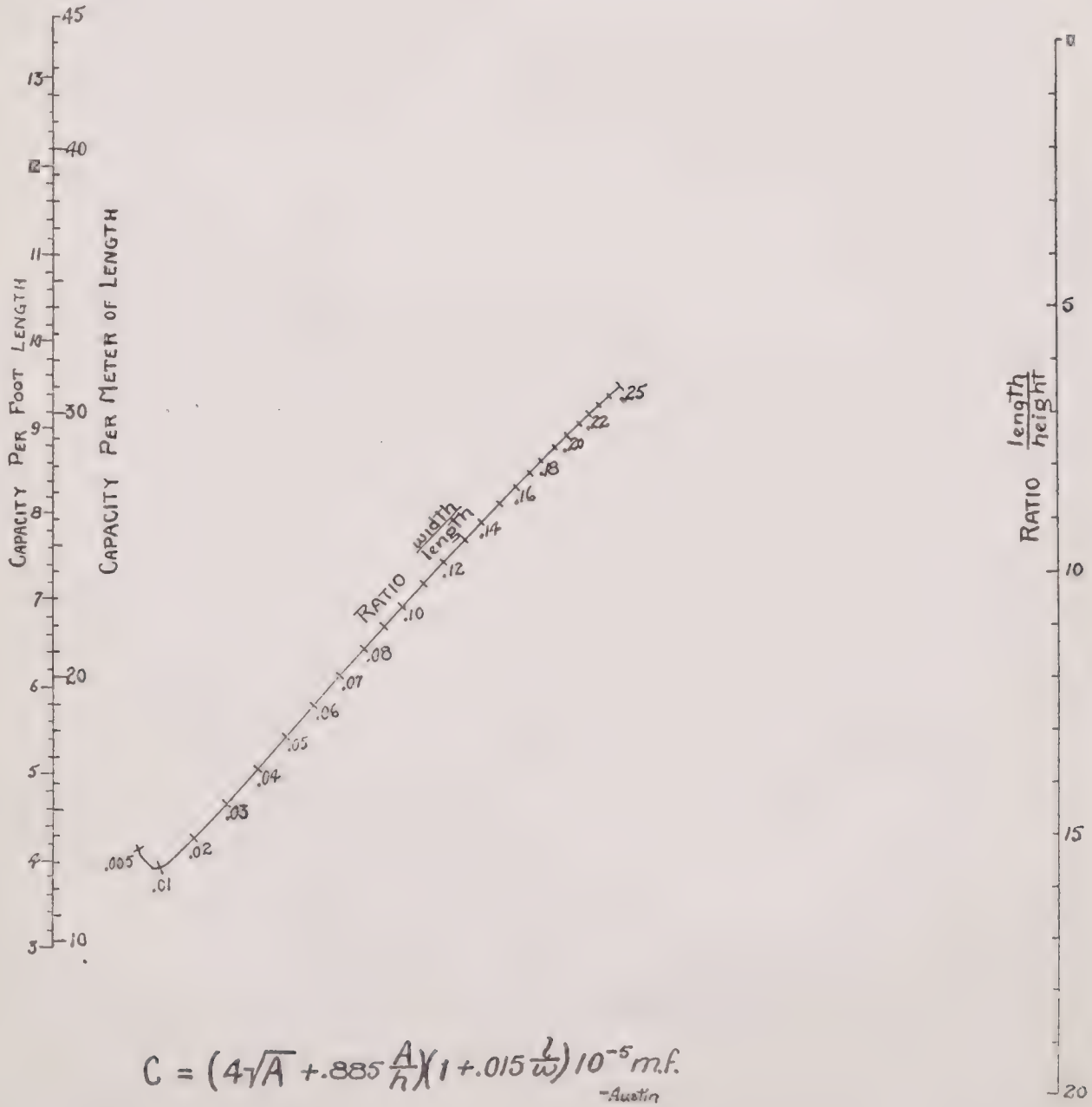
Capacity of a Multiple Wire Antenna

DR. L. W. AUSTIN has proposed a formula with which the capacity of the horizontal portion of a multiple wire antenna can be determined. The formula is reproduced on the chart below. The symbols in the formula represent:

A=area of flat top, in square meters,
h=height in meters,
l=length in meters,
w=width in meters.

The chart below may be used to solve this equation, when the dimensions of the flat top are known. On the scale at the right locate a point corresponding to the ratio of length to height. Thus an antenna 40 feet high and 200 feet long would have a length to height ratio of 5. On the sloping scale in the center determine a point corresponding to the ratio of width to length. Thus, if the above antenna was composed of six wires spaced 4 feet apart the width to length ratio is .10. Draw a straight line between these two points and extend until it intersects the capacity scale. The result will give the capacity per meter of length or per foot of length on opposite side of same scale, in micro-microfarads.

The capacity so determined does not include that due to the lead-in. The capacity may also be changed somewhat by surrounding metal structures.



$$C = (4\sqrt{A} + .885\frac{A}{h})(1 + .015\frac{l}{w})10^{-5}\ m.f.$$

-Austin

MEMORANDA

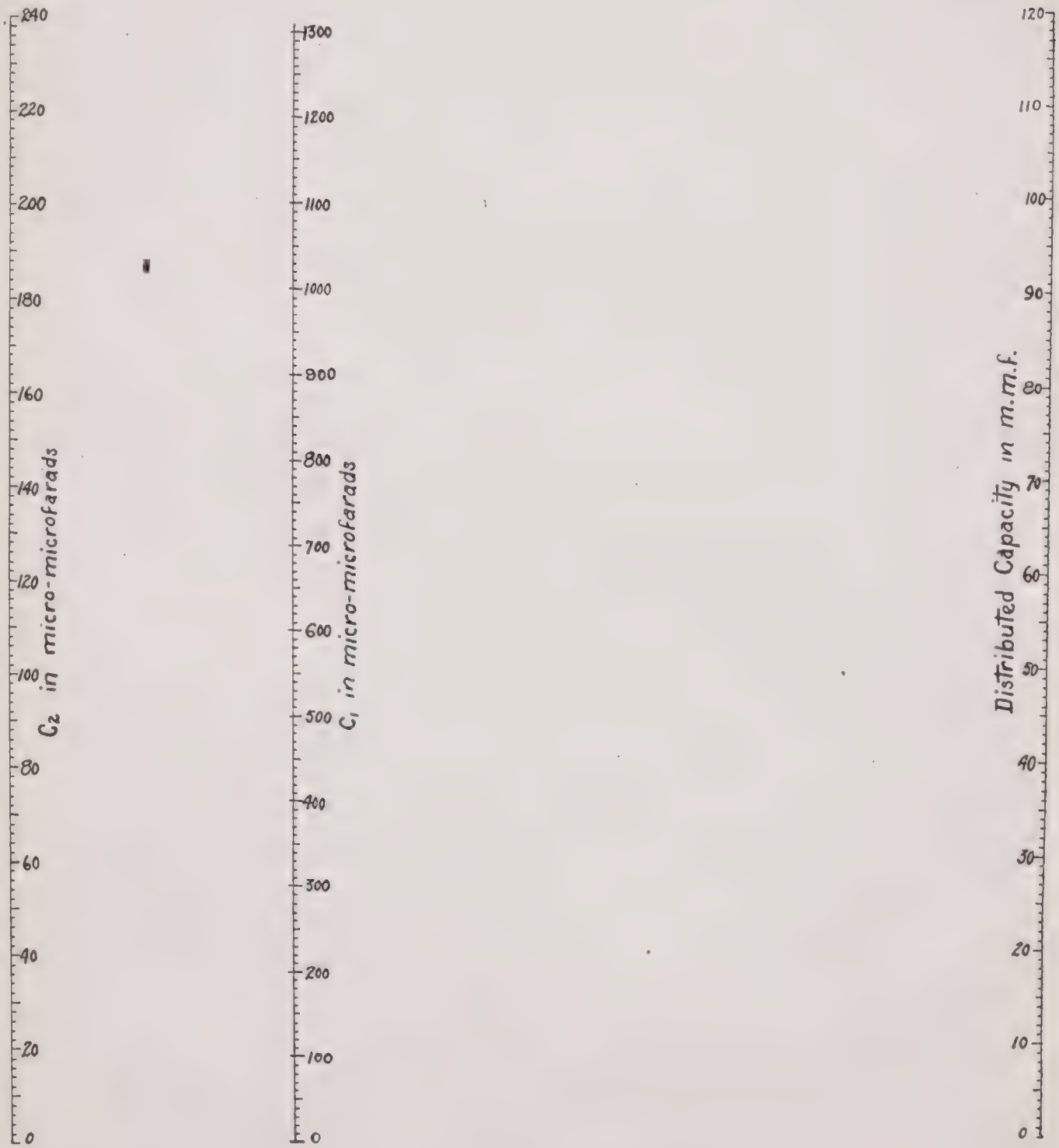
The Distributed Capacity of a Coil

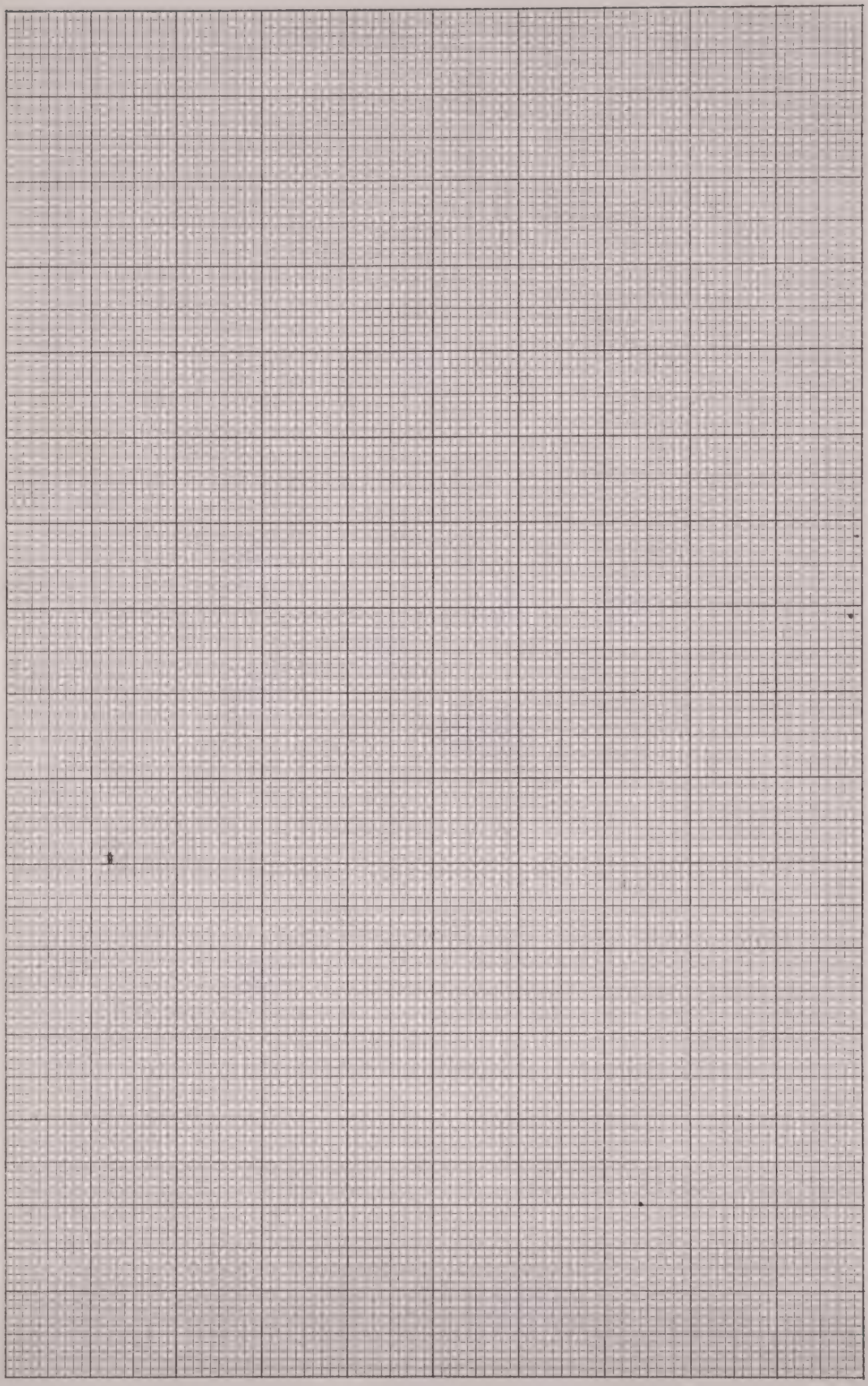
(1) Place a variable condenser across the terminals of the coil and determine the amount of capacity necessary (in addition to the distributed capacity) to obtain resonance with a certain wavelength. Call this value C_1.

(2) Find the capacity necessary on same condenser to obtain resonance with a wavelength one-half of the first value. Call this value C_2.

(3) Locate the values of C_1 and C_2 on the respective scales on the chart below and determine C_D on the third scale in usual manner.

Values are given in micro-microfarads on each scale. A micro-microfarad is 0.000,001 microfarad. Thus 800 m.m.f. are equivalent to .0008 m.f.

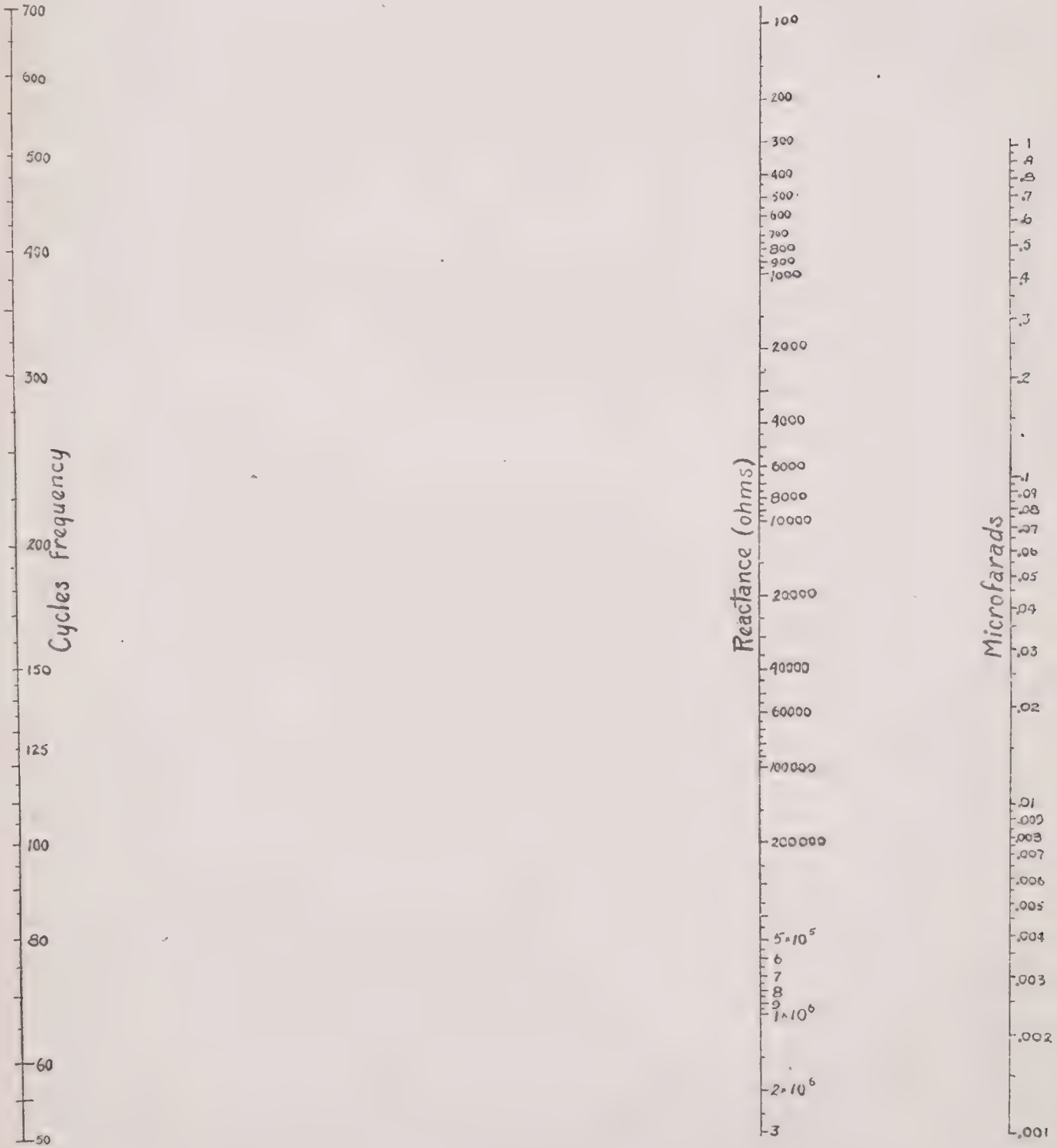




Reactance of a Condenser at Commercial Frequencies

THE reactance of a condenser (measured in ohms) is inversely proportional to its capacity and to the frequency. The symbol for condenser reactance in electrical formulas is generally X_C. The chart below gives the reactance of a condenser at frequencies ranging from 50 cycles to 700 cycles.

This chart is used in the same manner as the preceding charts.



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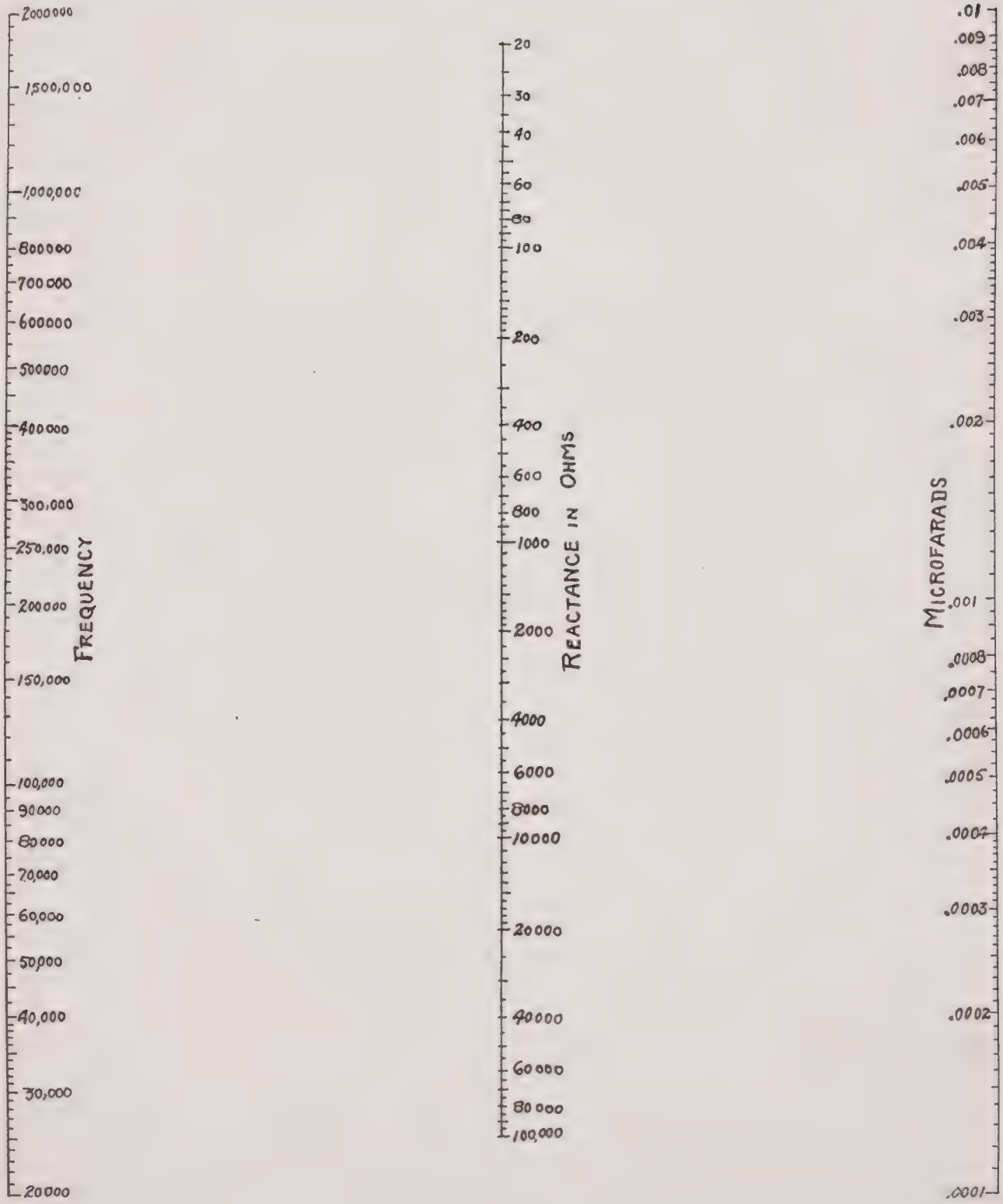
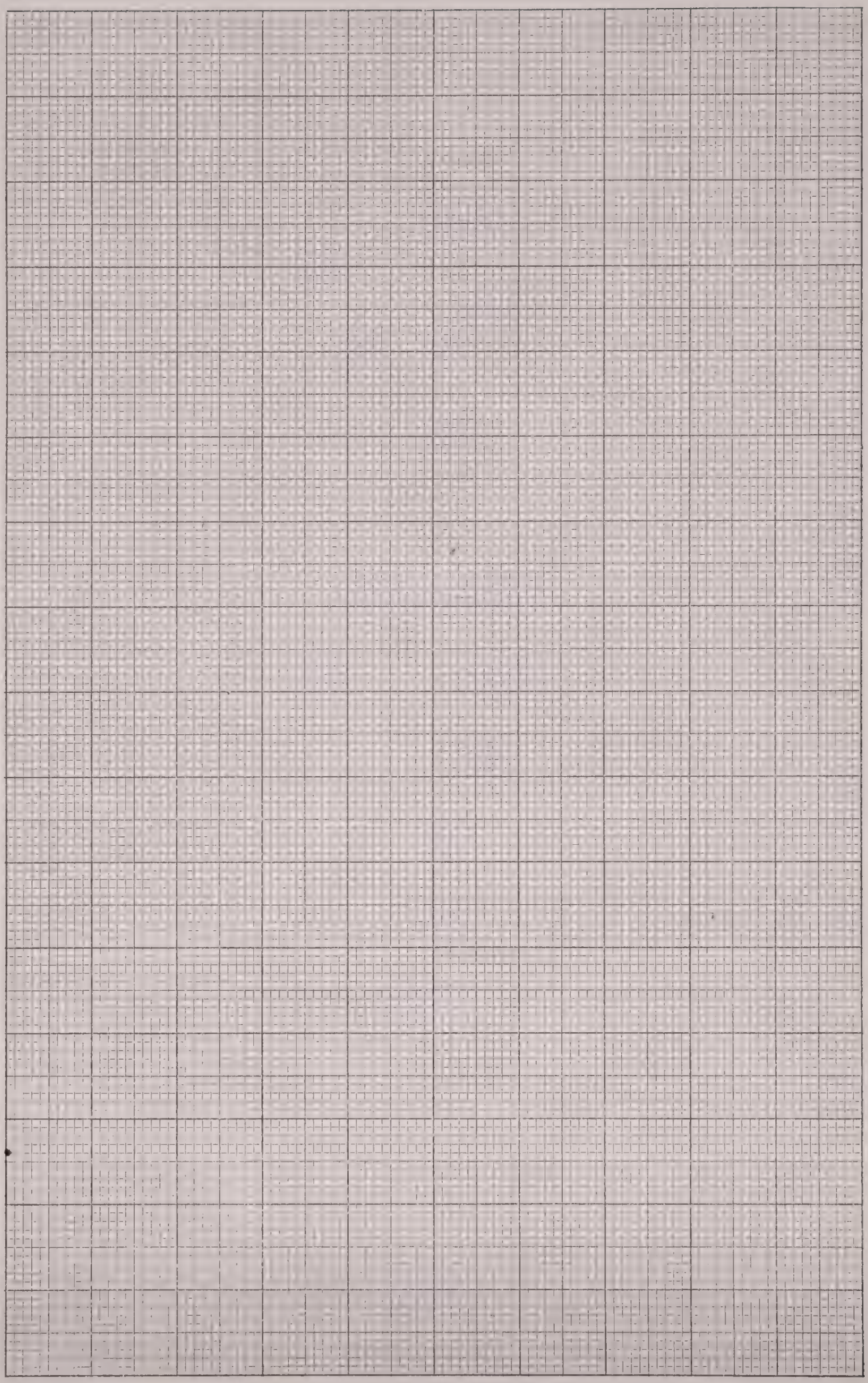
Reactance of a Condenser at Radio Frequencies

THIS is the same as preceding chart, except it is designed for radio frequencies, from 20,000 to 2,000,000 cycles.



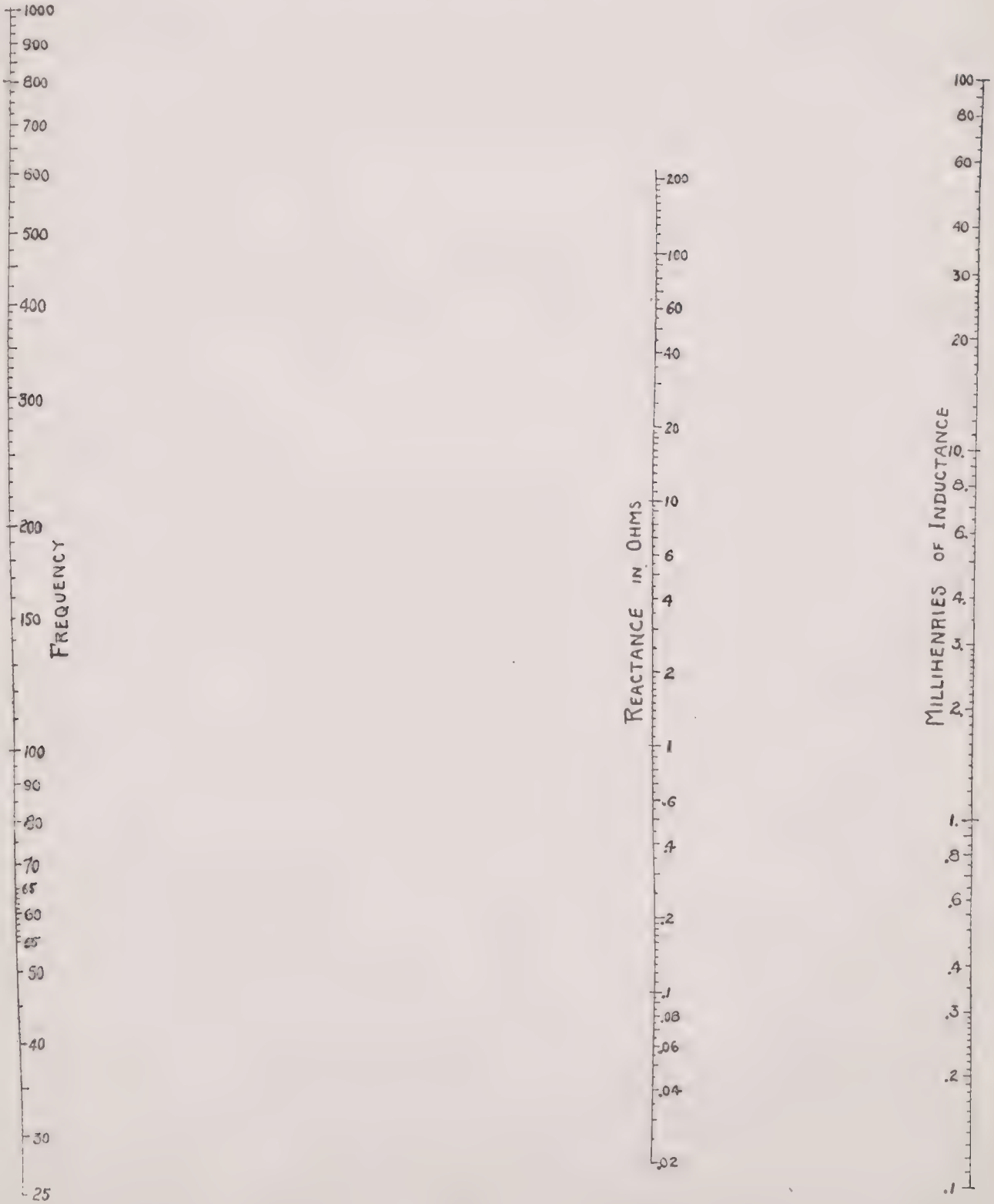


Reactance of an Inductance at Commercial Frequencies

A LINE connecting points on the left and right scales corresponding to the frequency and the inductance in millihenries, will intersect the "Reactance" scale at a point that will indicate the reactance in ohms that is introduced into the circuit by the inductance.

For values of inductance from 100 millihenries (.1 henry) to 100 henries consider values on "Capacity" scale as .1 to 100 henries, and multiply values of reactance on scale in center by 1000.

For telephone frequencies between 250 cycles and 10,000 cycles multiply values on both "Frequency" and "Reactance" scales by 10.



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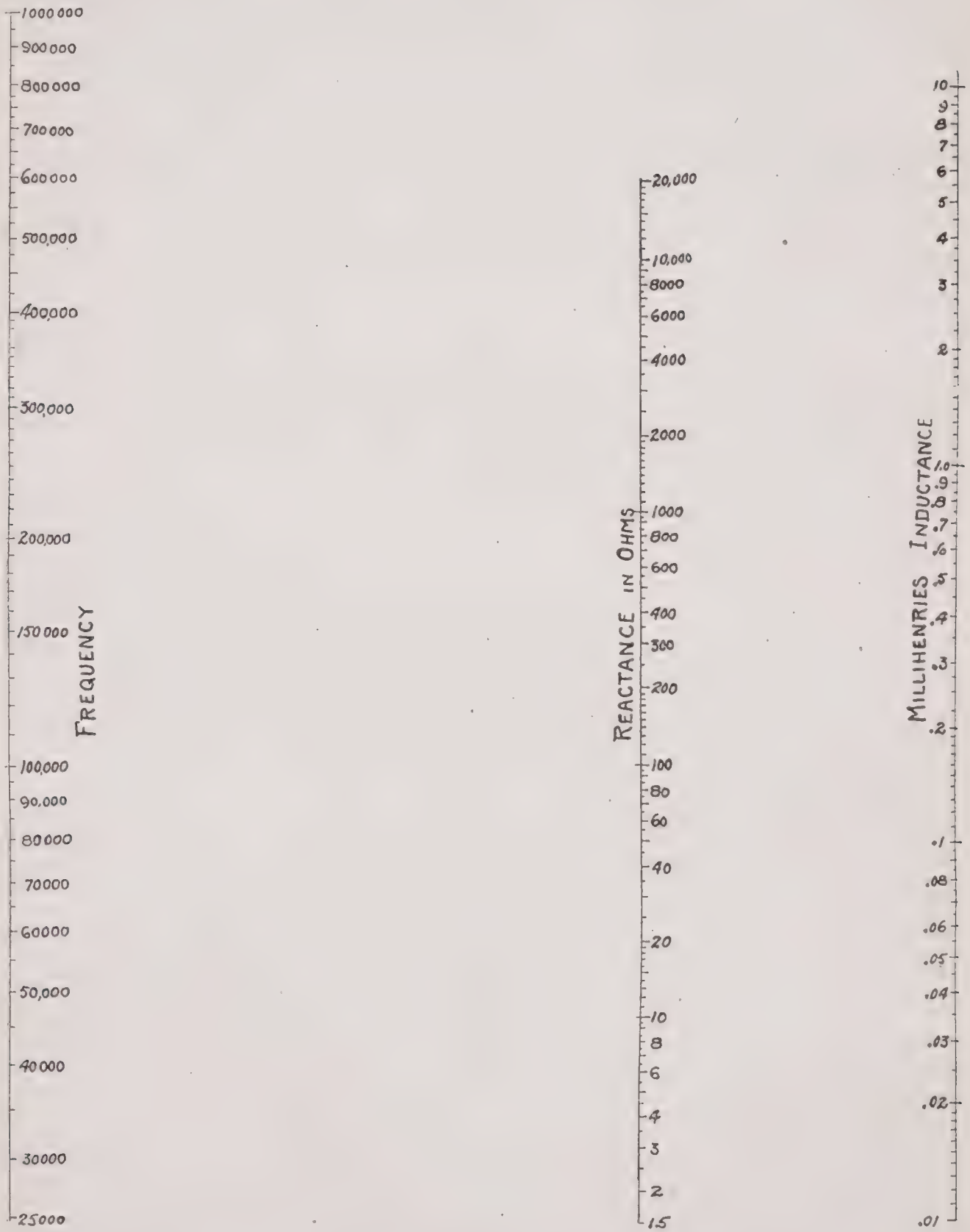
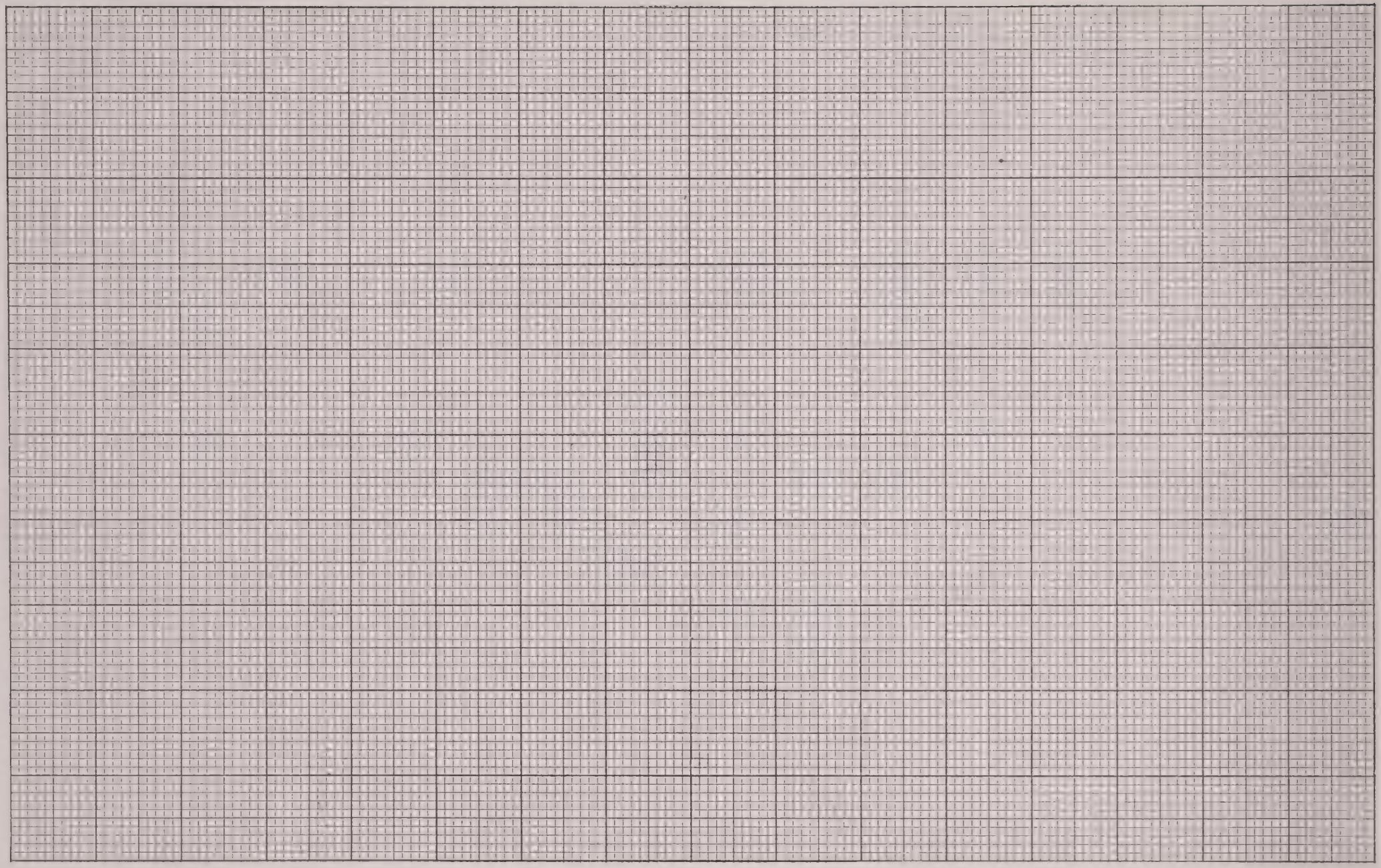
Reactance of an Inductance at Radio Frequencies

Use same method as on preceding chart.

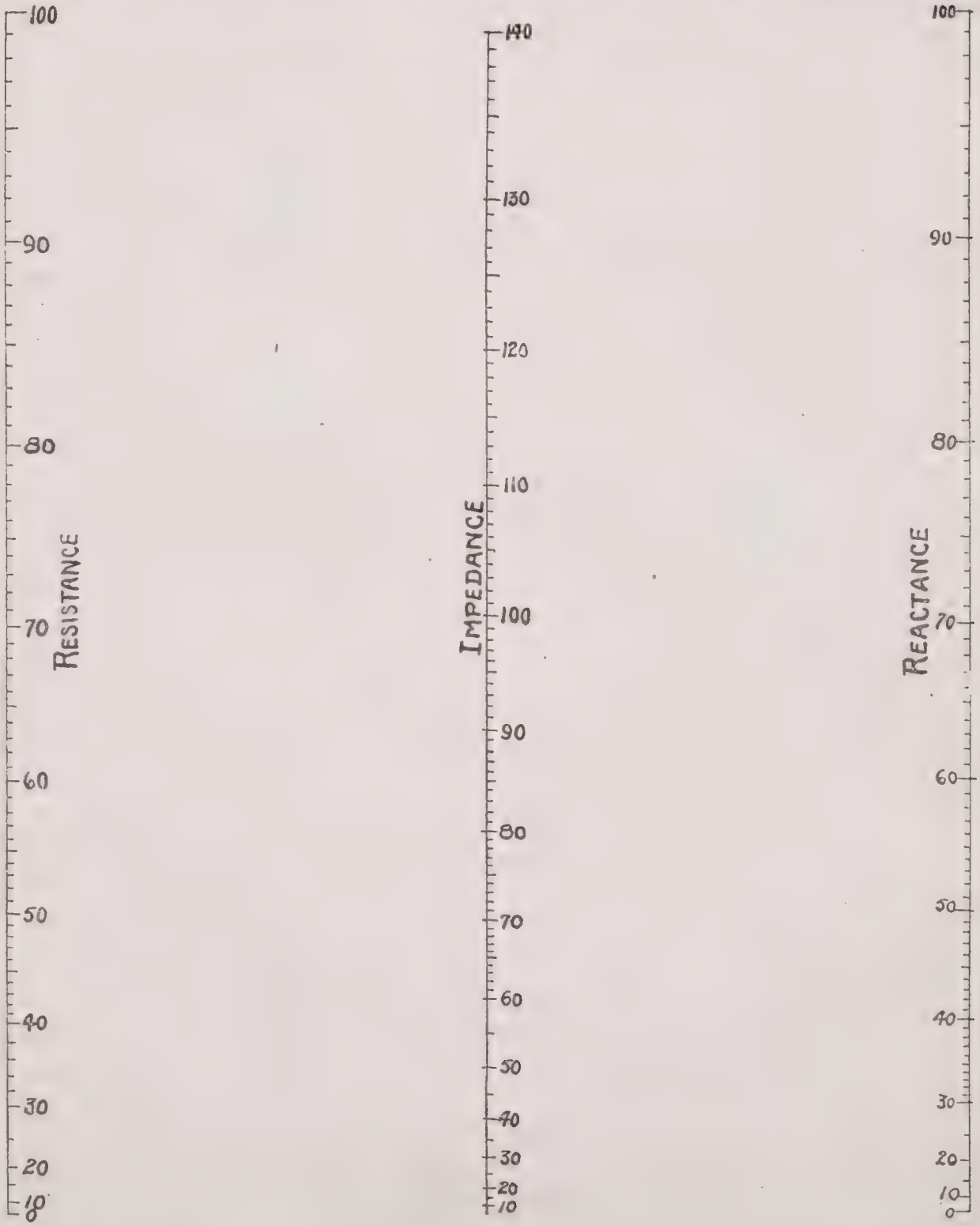




Impedance, Reactance, Resistance

IN alternating current practice the term "impedance" is used to denote the total effect of resistance and reactance when both are present in the circuit at the same time. The relation between these factors is represented in the following chart. Here the scales are graduated between 10 and 100. These units may be taken to represent ohms directly, or the values on all the scales may be multiplied by any factor such as .001, .01, .1, 10, or 100, as the case demands. The same factor must be used on each scale. If the ratio between the resistance and reactance is greater than 10 to 1 or 1 to 10 the accuracy of the chart is not very great, so such values have been omitted. Generally speaking, in this case the effect of the smaller of the two is not great enough to consider.

Thus: Suppose R=10 and X=1, then the impedance is equal to 10.05, which is very little more than the value of the resistance itself. In solving problems a straight-edge is applied to the scales in the same way as described for preceding charts.



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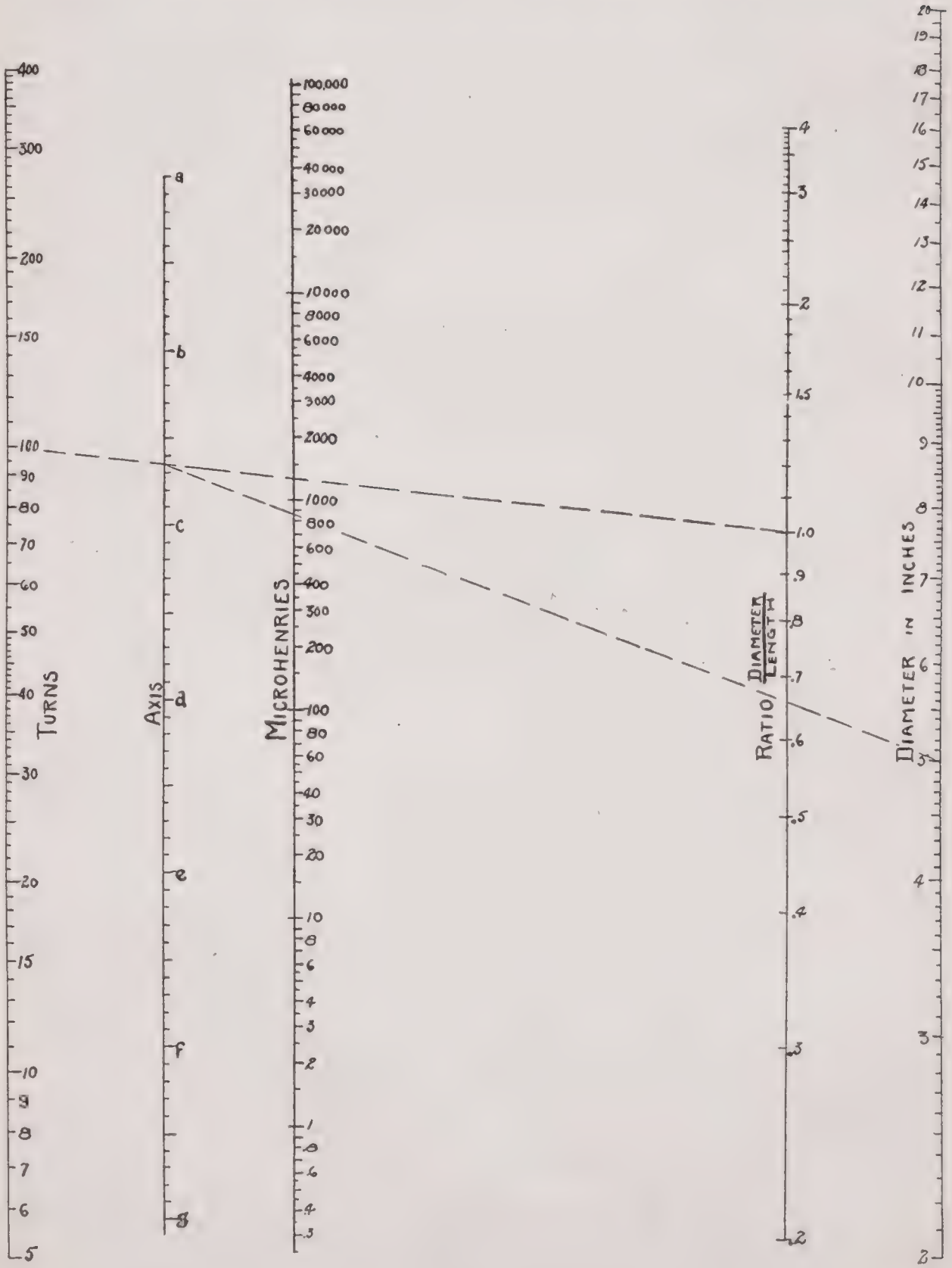
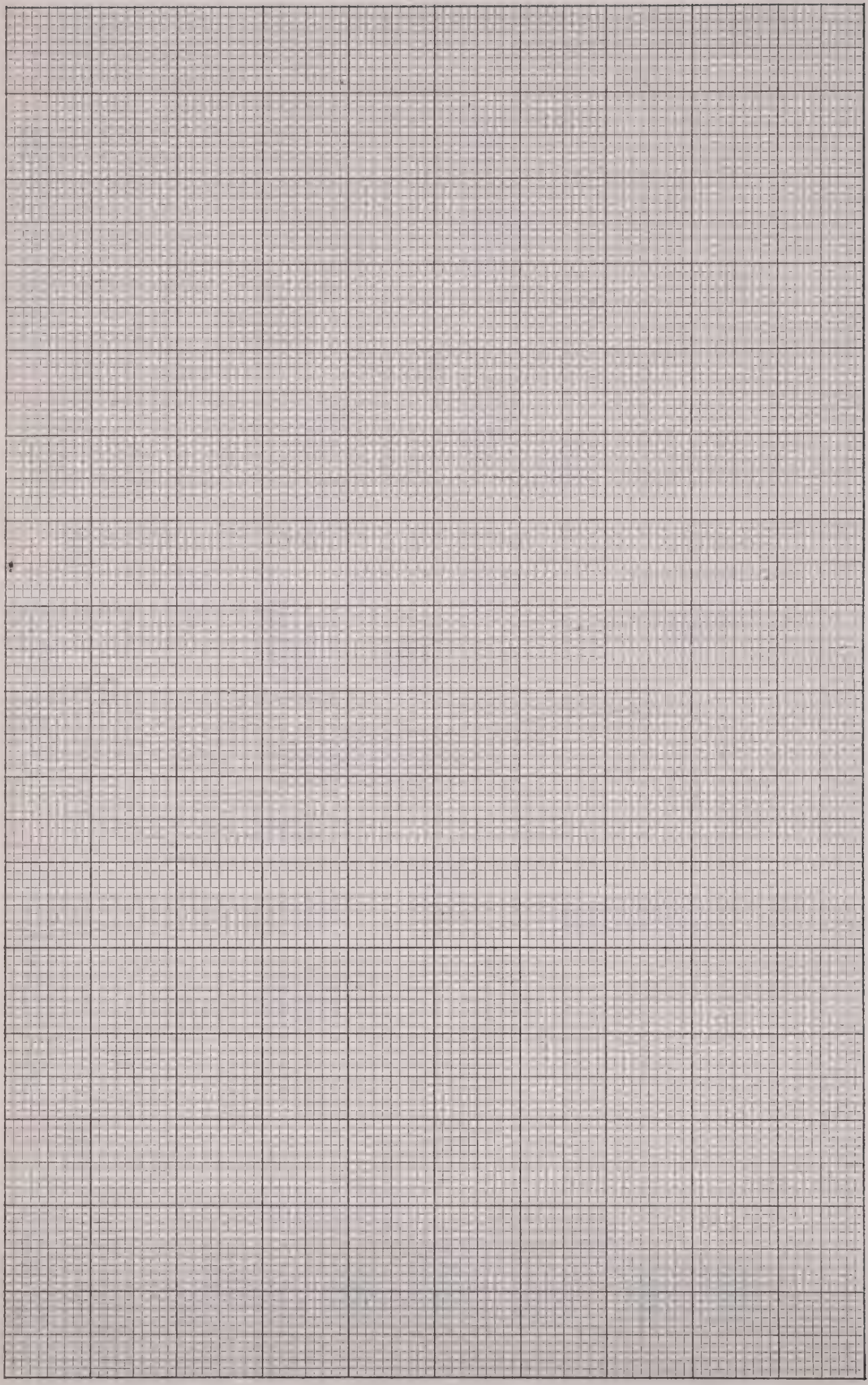
Inductance of Single Layer Coils

DETERMINE where a line connecting points on scales 1 and 5 corresponding to the total number of turns, and the ratio in diameter to length respectively, will cut the Axis (scale 2). Between this point on the axis and a point on scale 5 corresponding to the diameter construct a line to intersect the center scale at a point corresponding to the number of microhenries of inductance.

This value must be corrected for the effect of the insulation space and number of turns by using charts on pages 49 and 51 if additional accuracy is necessary.



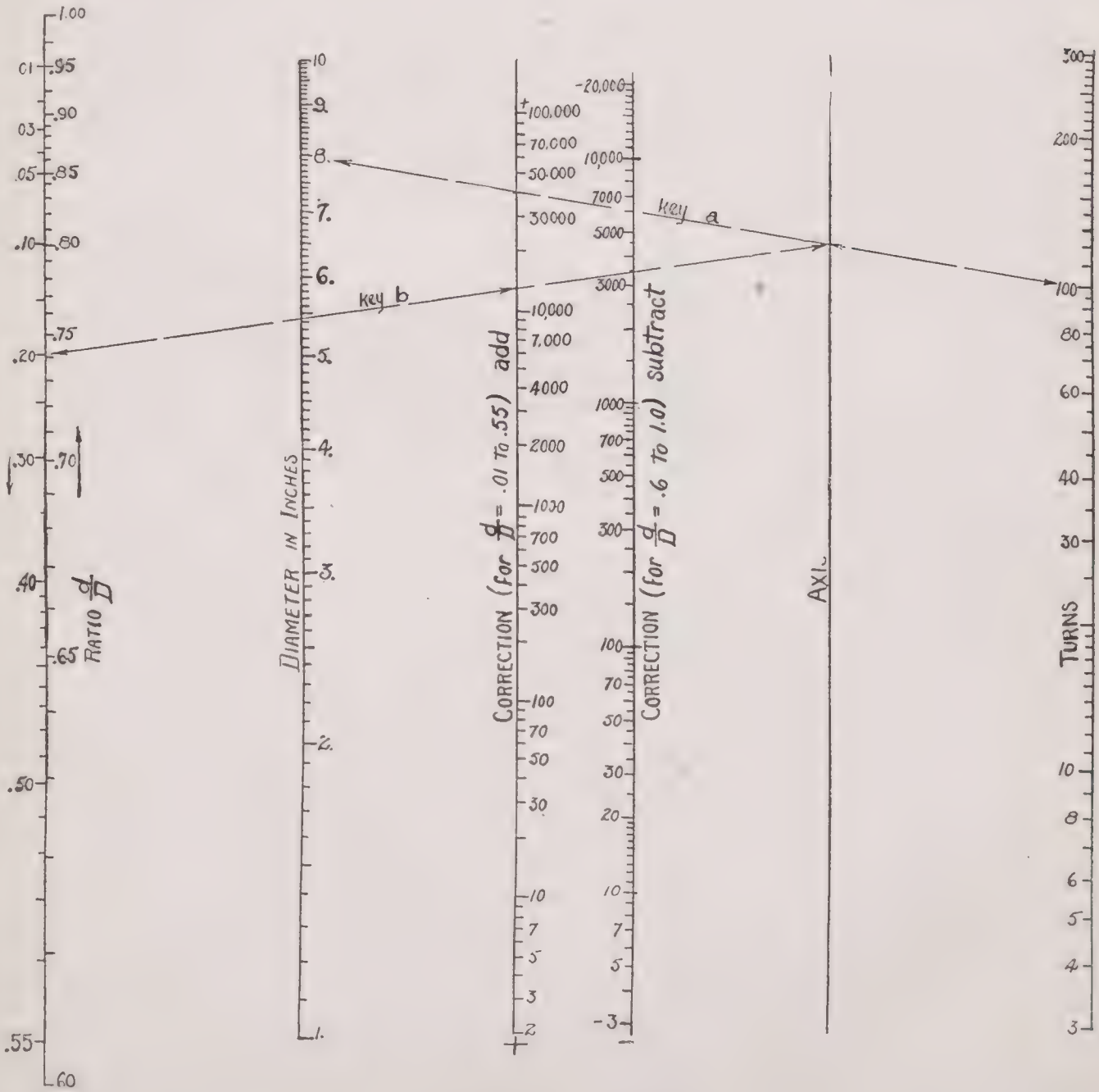


Correction Factor for Current Sheet Inductance Formulas

Correction for the space taken up by insulation

ORDINARY formulas generally used in computing the inductance of coils do not include the effect of the space between the wires. "d"=the diameter of the bare wire, and "D"=the total diameter of wire, including the insulation. When d/D has a value below .55 the correction term must be added. When d/D is above .60 the term must be subtracted.

Select points on the diameter and turns scales to correspond to the values for the coil under consideration. Determine the point where a line between these points will intersect with the axis. Determine the ratio of the diameter of the wire bare to total diameter, including insulation. The latter value is equal to the pitch. Locate the value of this ratio on the d/D scale. For ratios below .55 this point will be on the outside. For values above .60 the point will be found on the inside of this scale. The correction term will be found on one of the two center scales at a point where indicated by key line "b" with the solution shown. The value is given in centimeters. 1000 centimeters of inductance are equal to 1 microhenry.



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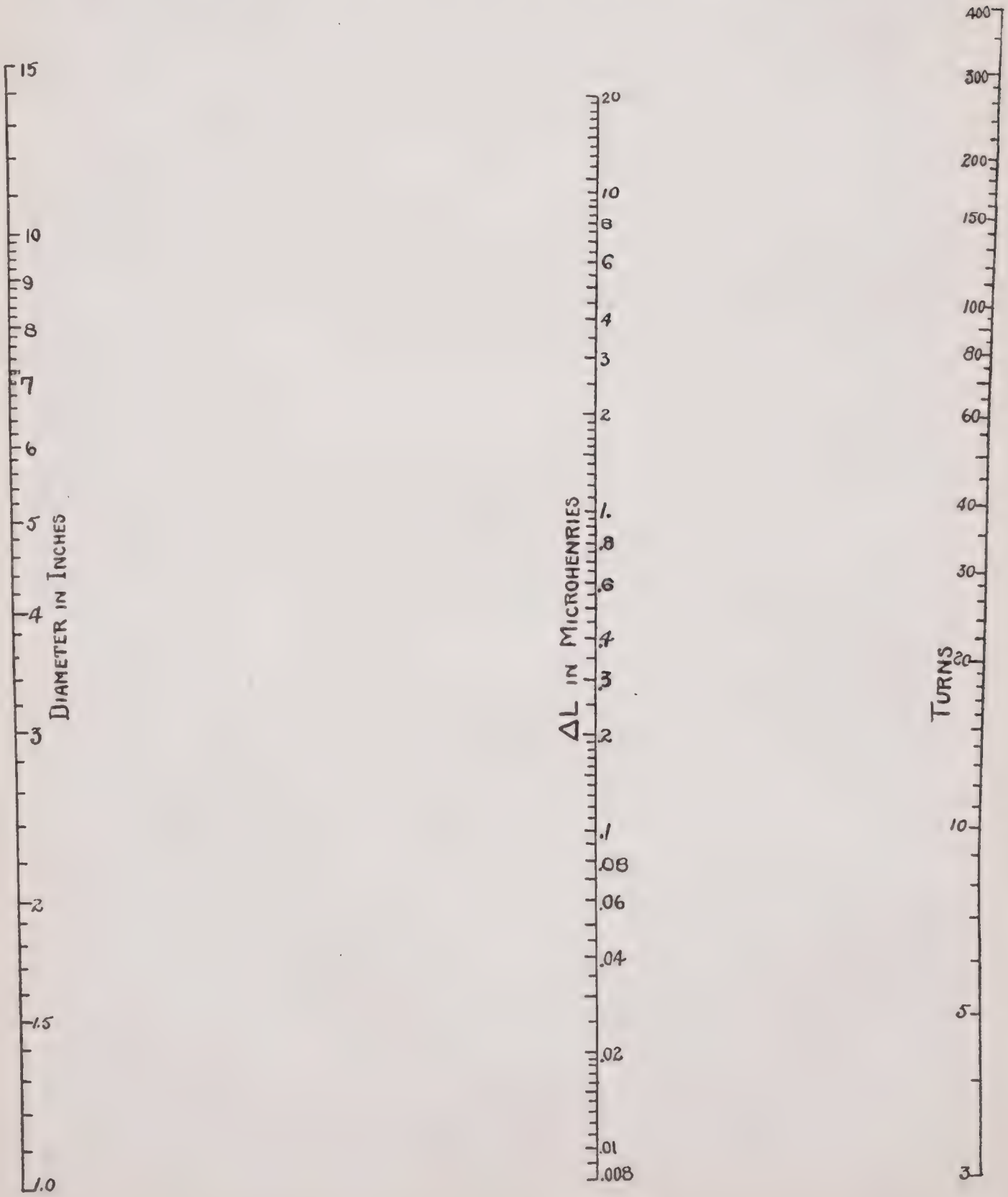
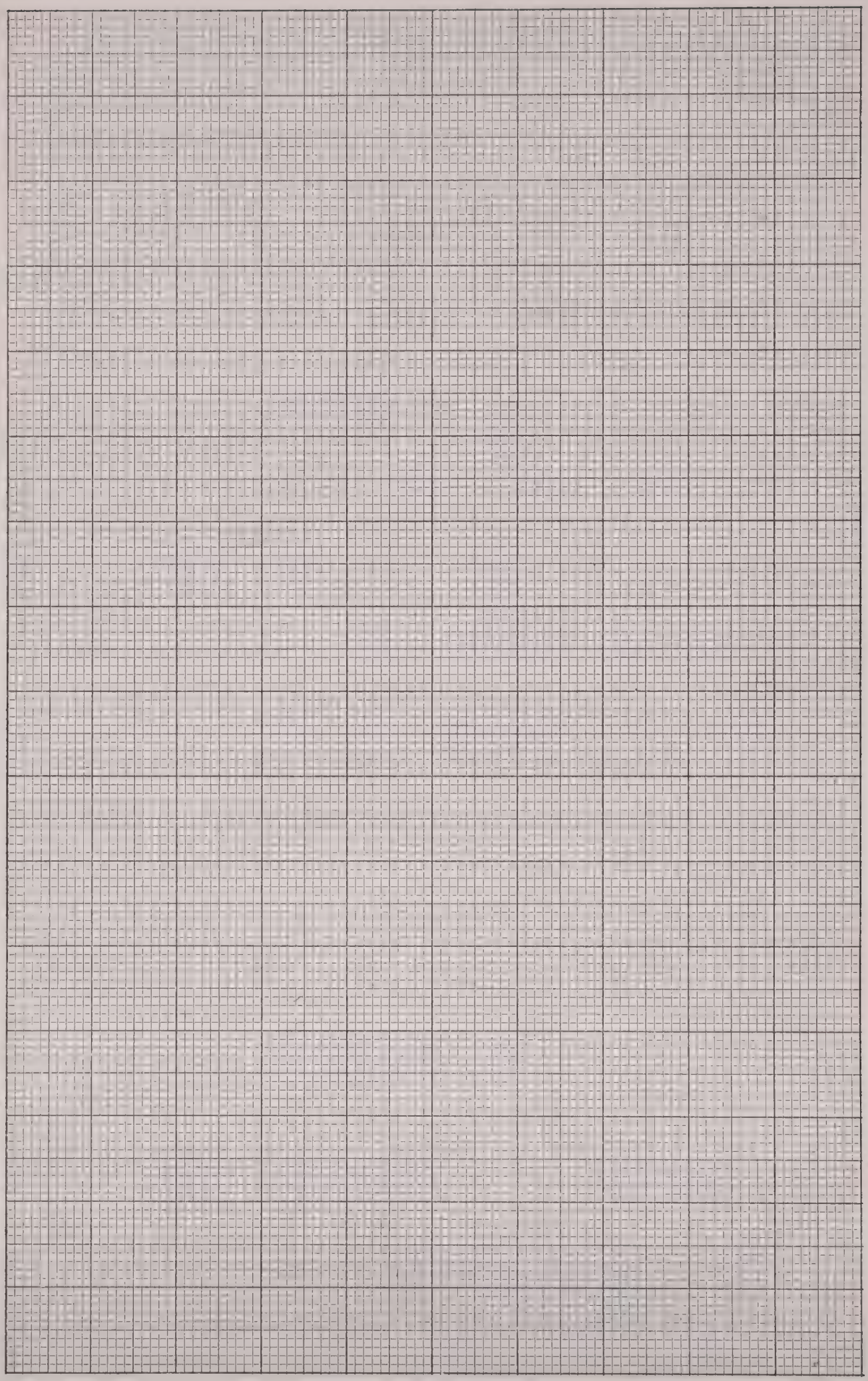
Correction Factor for Inductance Formulas

Correction for number of turns on single layered coils

NEARLY all inductance coil formulas are derived by considering the equivalent current sheet to represent the coil. A correction term must, therefore, be applied whenever approximate values are not desired. Use the chart as previously described.

The correction factor for coils having diameters from 1 to 15 inches and wound with from 3 to 400 turns may be determined from chart below. This gives, on the center scale, a certain number of microhenries, which value must be subtracted from the value of inductance computed with any current sheet formula.





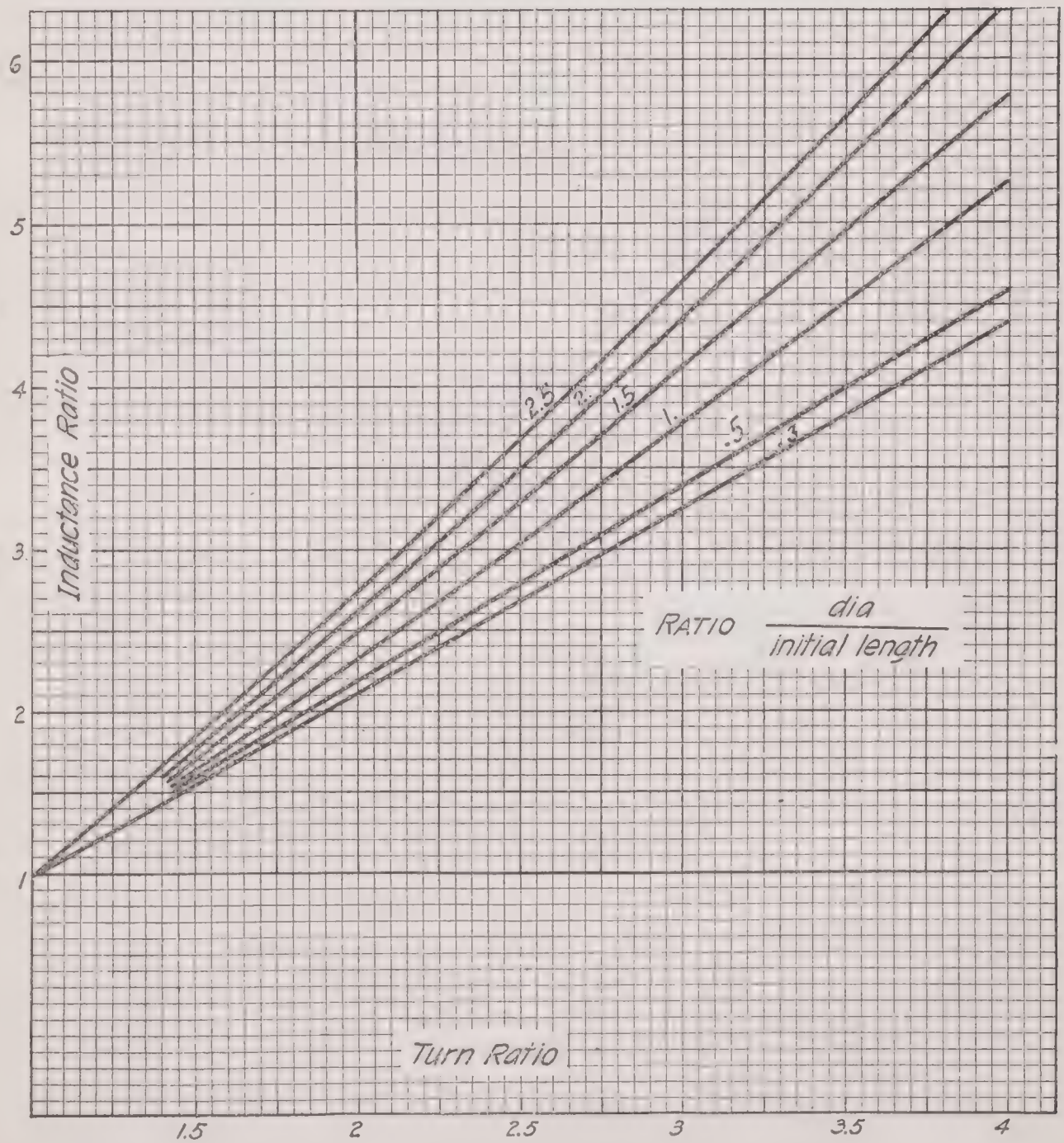
Single Layer Inductance Coil Design

TO design a coil for a given inductance when the quantities known are the diameter of the cylinder and the number of turns per inch (or the size of wire). Assume a value for the number of turns and determine the inductance of such a coil using charts on pages 15 and 47. Such a coil is used as a reference.

If the inductance value so obtained is called unity, and the value desired is between 20% and 500 % of this value, the correct number of turns to use can be obtained from the following curves.

Example: The diameter to length ratio of the reference coil was equal to 2. A coil is desired that has an inductance equal to 65% of the inductance of this coil. Referring to page 55 it is found that the coil must have 75% of the number of turns assumed for the reference coil. Another coil is desired having 4.1 times the inductance of the reference coil. Chart below shows that it must have 2.80 times as many turns.

The curves may also be used to locate taps on coils to obtain predetermined divisions of inductance.



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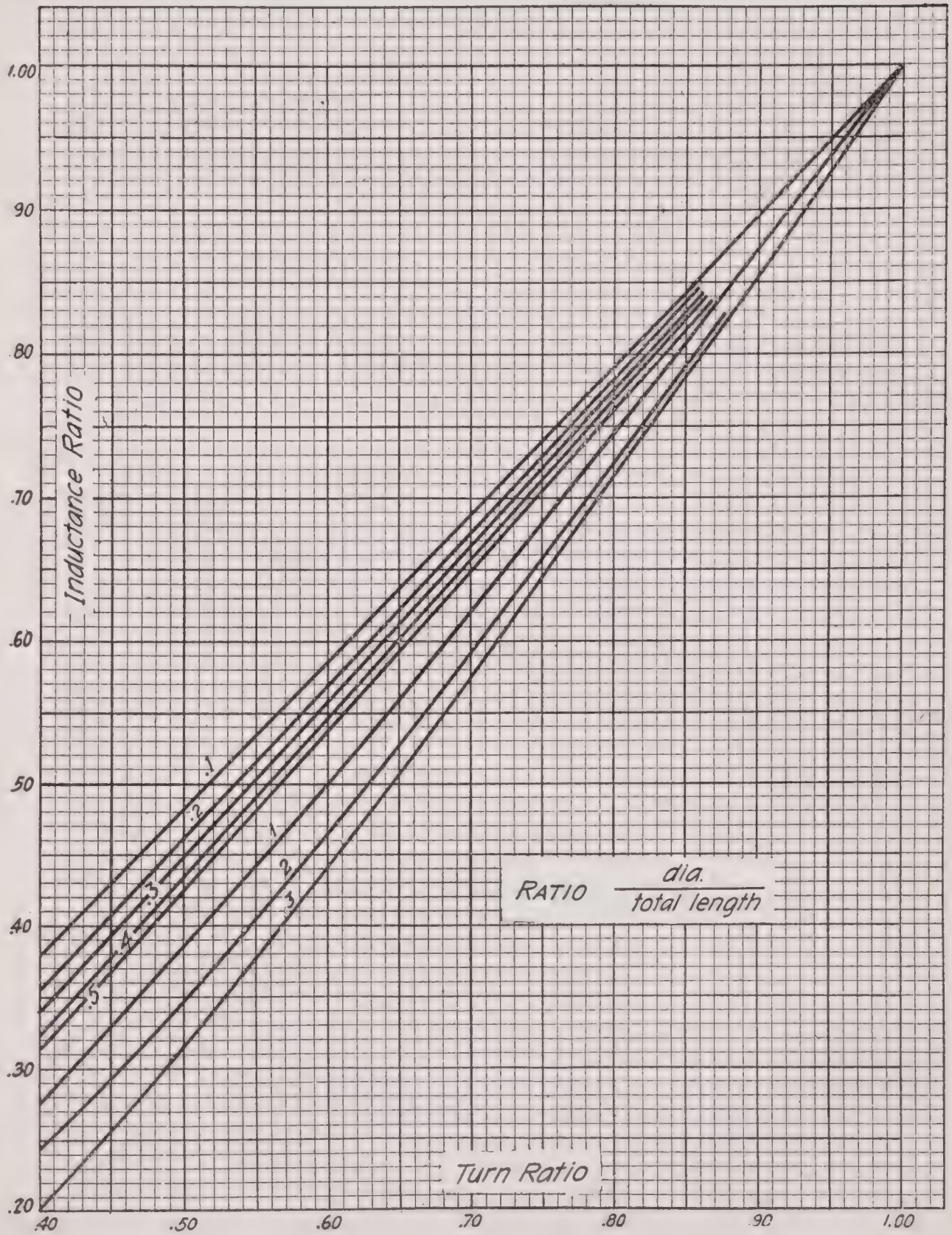
Single Layer Inductance Coil Design

See Preceding Chart for Use

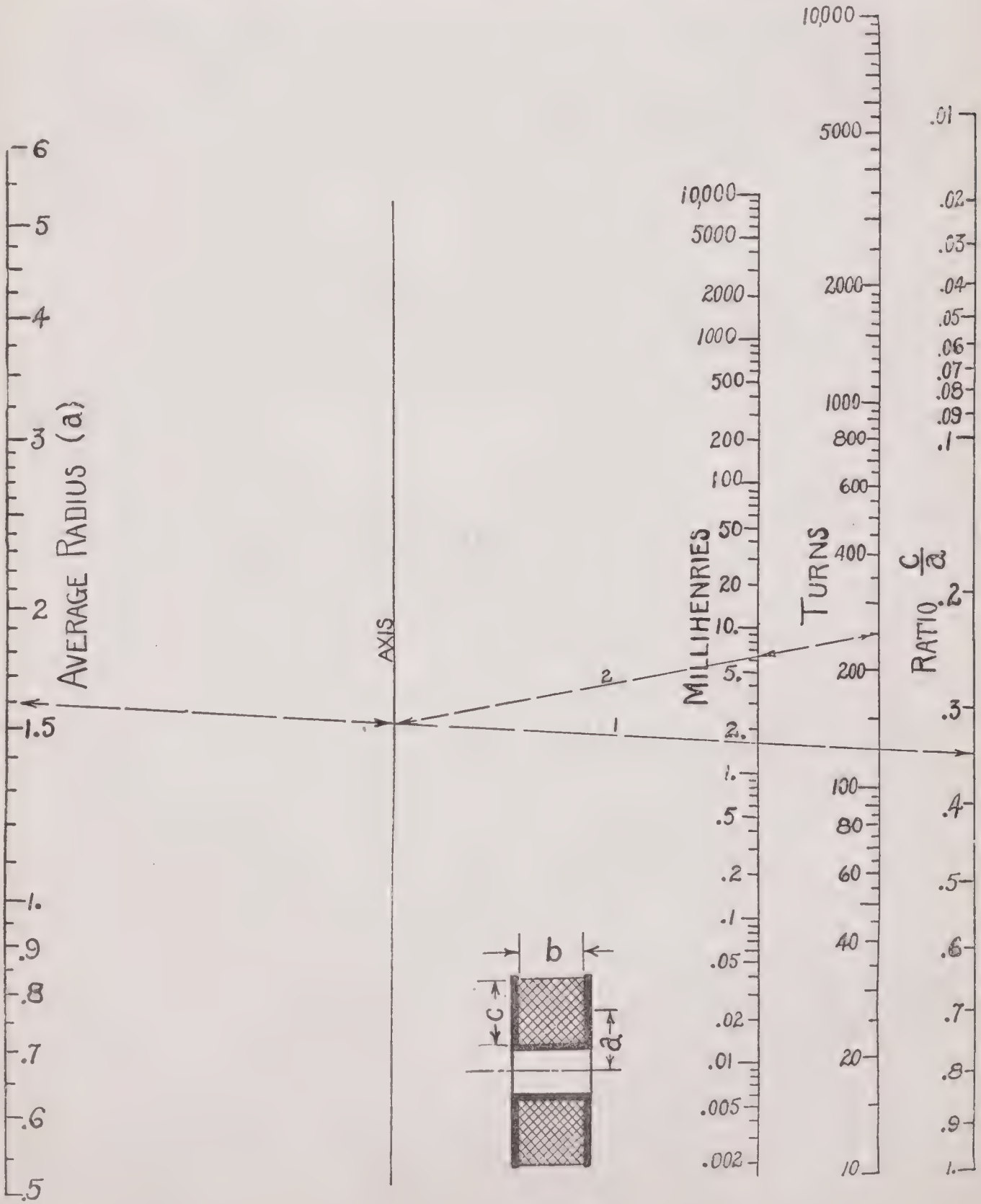
To be used when coil desired is to have less inductance than the reference.



Inductance of a Multilayered Coil

WHEN the mean radius (a), length (b), depth of winding (c), and number of turns are known. All measurements are in inches.

First compute the values of the ratios c/a and b/c. On the chart a line between the "a" and "c/a" scales (as key 1) will intersect the axis. At this point determine where a line to the "turn" scale will intersect the "millihenries" scale. If b=c the inductance may be read directly from this scale. Otherwise multiply the value obtained by a shape factor obtainable from curves on page 59, following.



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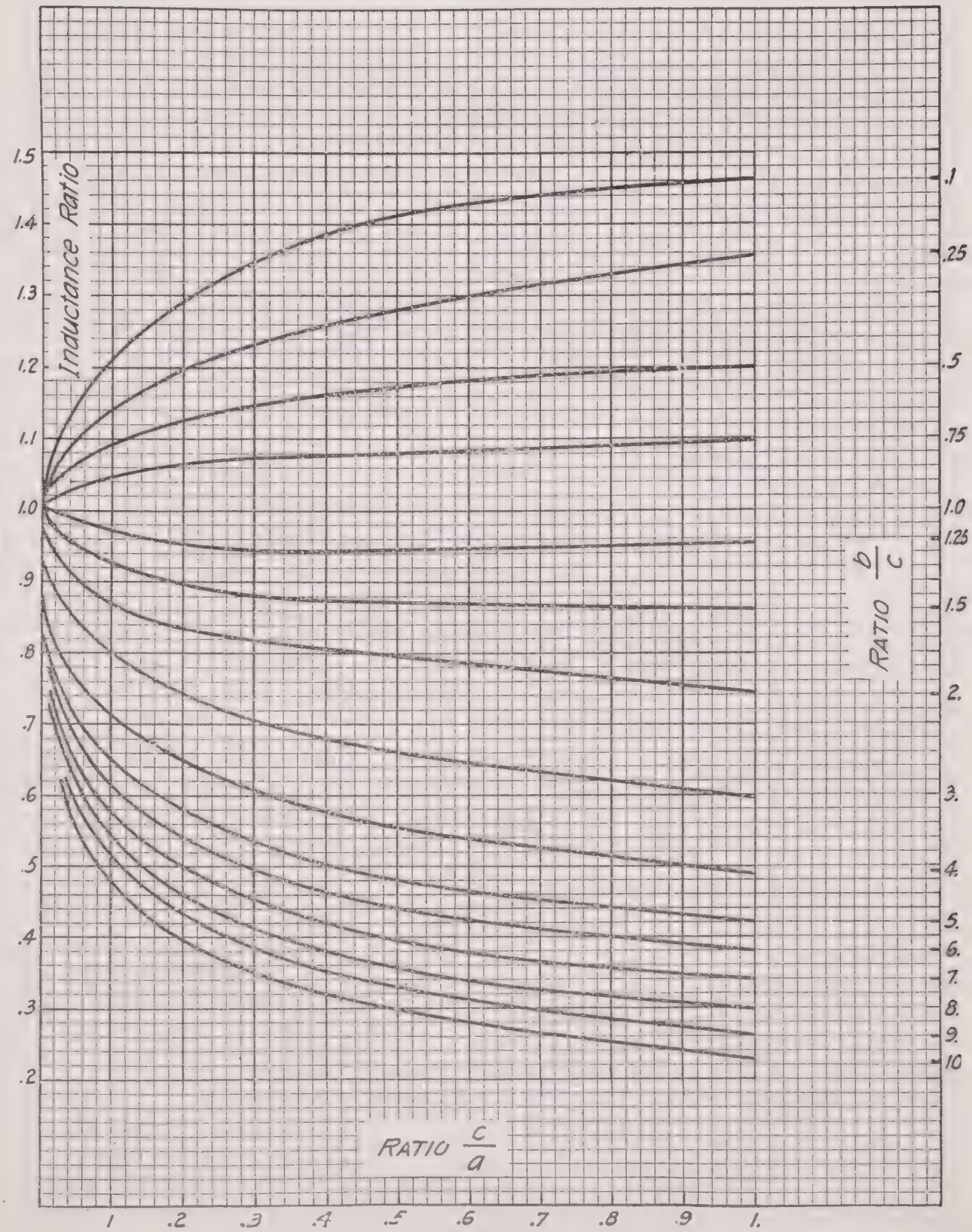
Shape Factor for Multilayered Inductance Coils

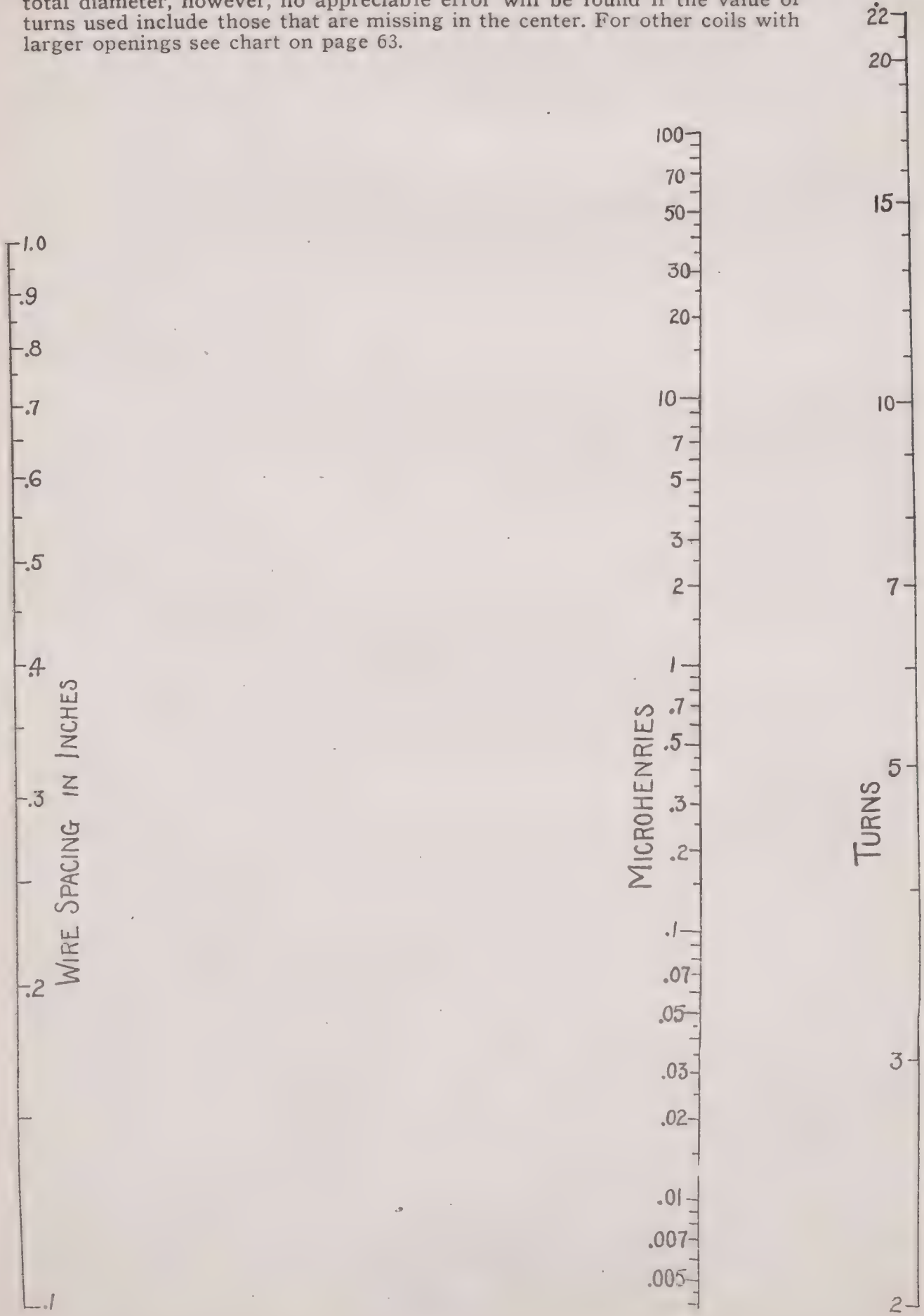
WHEN the length of the coil "b" does not equal the winding depth "c" the value of inductance obtained on preceding chart must be multiplied by a factor from the curves below. The scale at the bottom represents the ratio c/a, which was used on preceding chart. Separate curves represent values of b/c from 0.1 to 10. .Interpolate between curves if necessary, and read the value of shape factor at the left.

Example: If b/c in problem indicated on preceding chart is equal to 1.6 the value of inductance found there must be multiplied by .86, i.e., 6.2×.86=5.3 millihenries.



Inductance of a Spiral Wound Coil

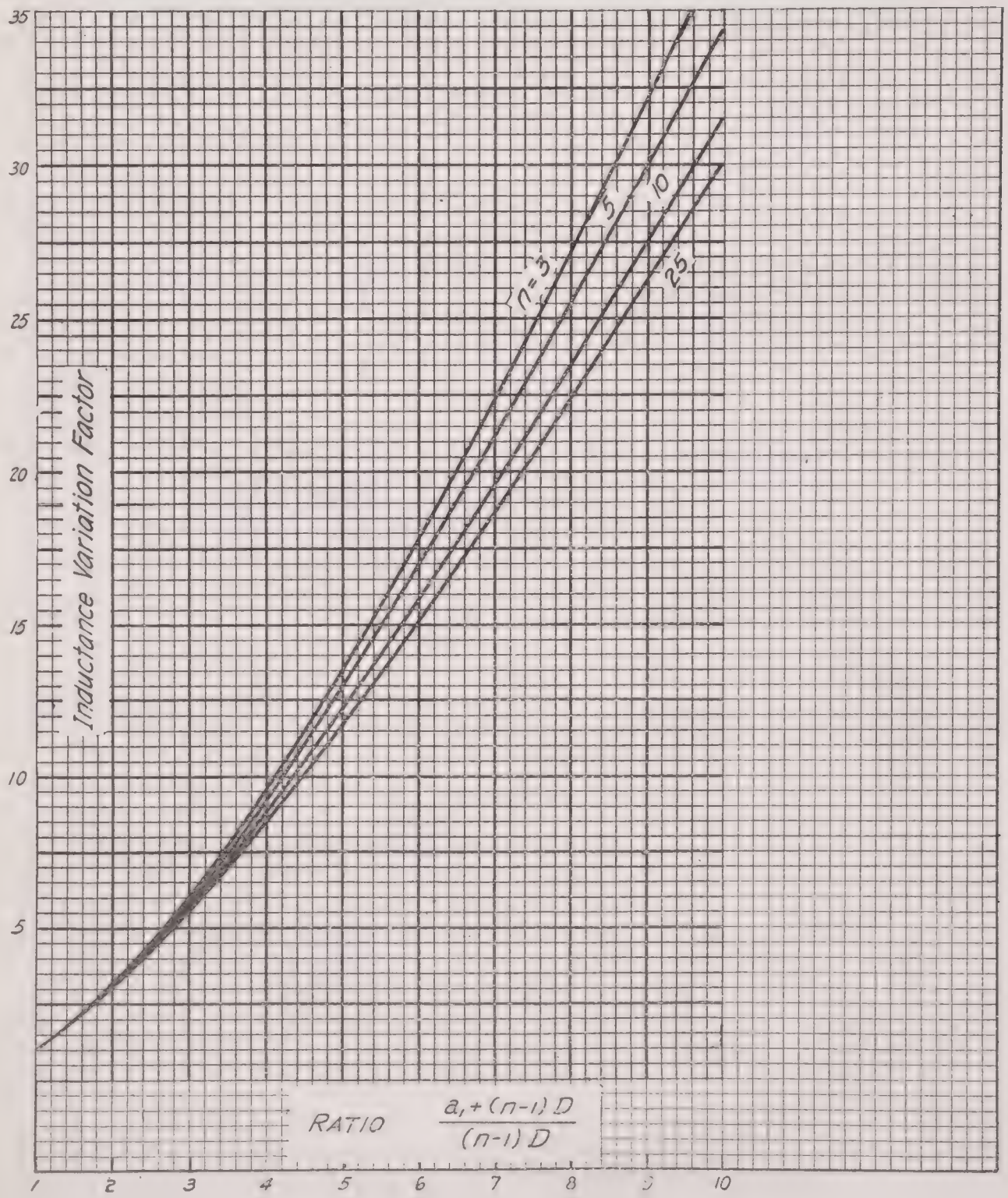
GREATEST accuracy is found with this chart when the width of the ribbon or conductor is approximately equal to the spacing between turn centers, and when the turns extend clear into the center. If the central opening is less than 10% of the total diameter, however, no appreciable error will be found if the value of turns used include those that are missing in the center. For other coils with larger openings see chart on page 63.

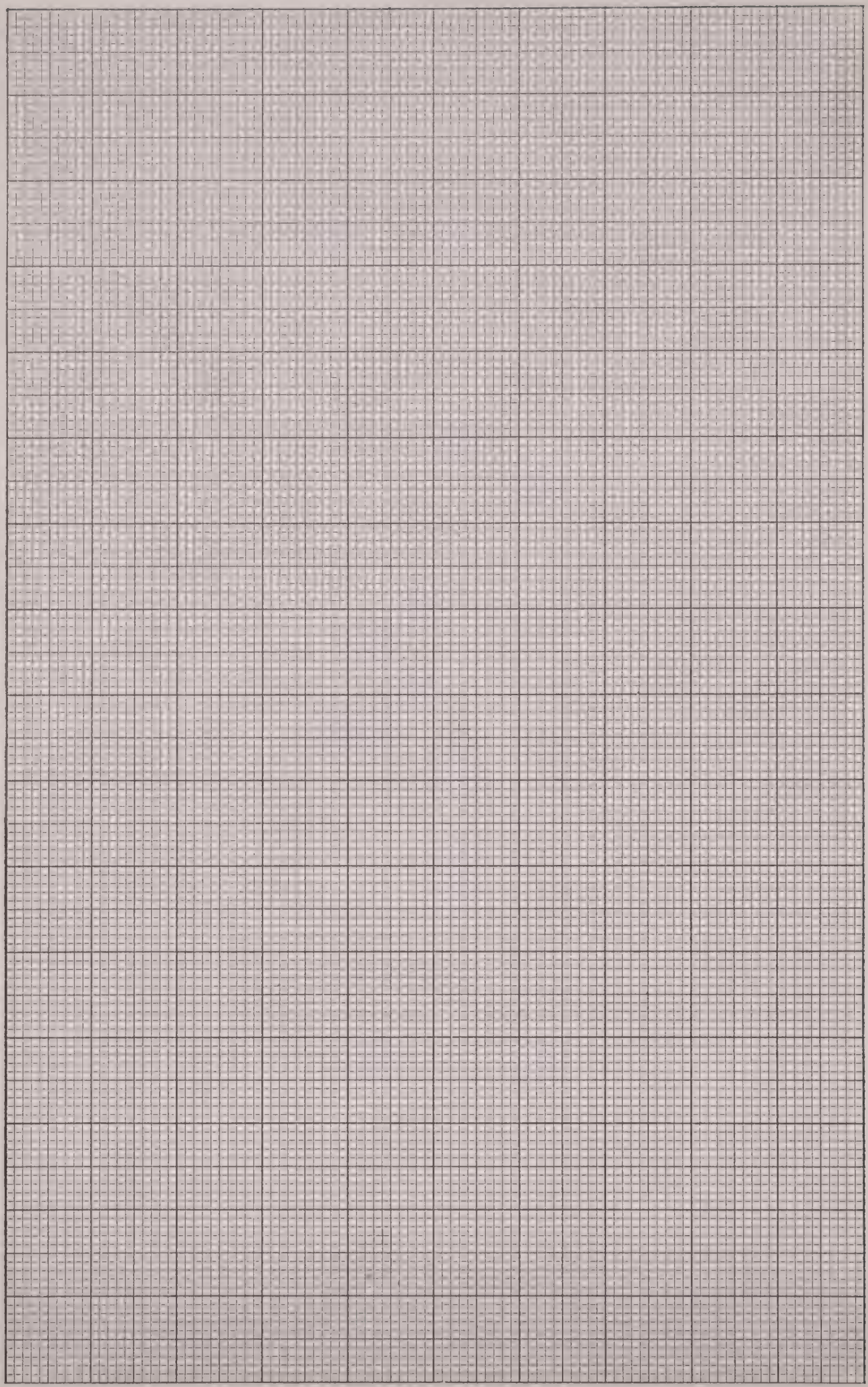


Inductance of Spiral Wound (Pancake) Coils

WHEN the central opening of the spiral exceeds 10% of the diameter of the coil the preceding chart used alone is not accurate. To obtain the correction factor compute or measure the value of the ratio of the diameter of the outer turn to the actual depth of winding: (using the expression at the bottom of the curve sheet if desired—in which a_1 is the diameter of inner turn, n is the actual number of turns and D is the spacing of turns).

Use preceding chart as before, except n=actual turns, and multiply the value of the inductance so obtained by the inductance variation factor from the curve, interpolating values if necessary between lines when n is equal to some value not represented by a separate curve.





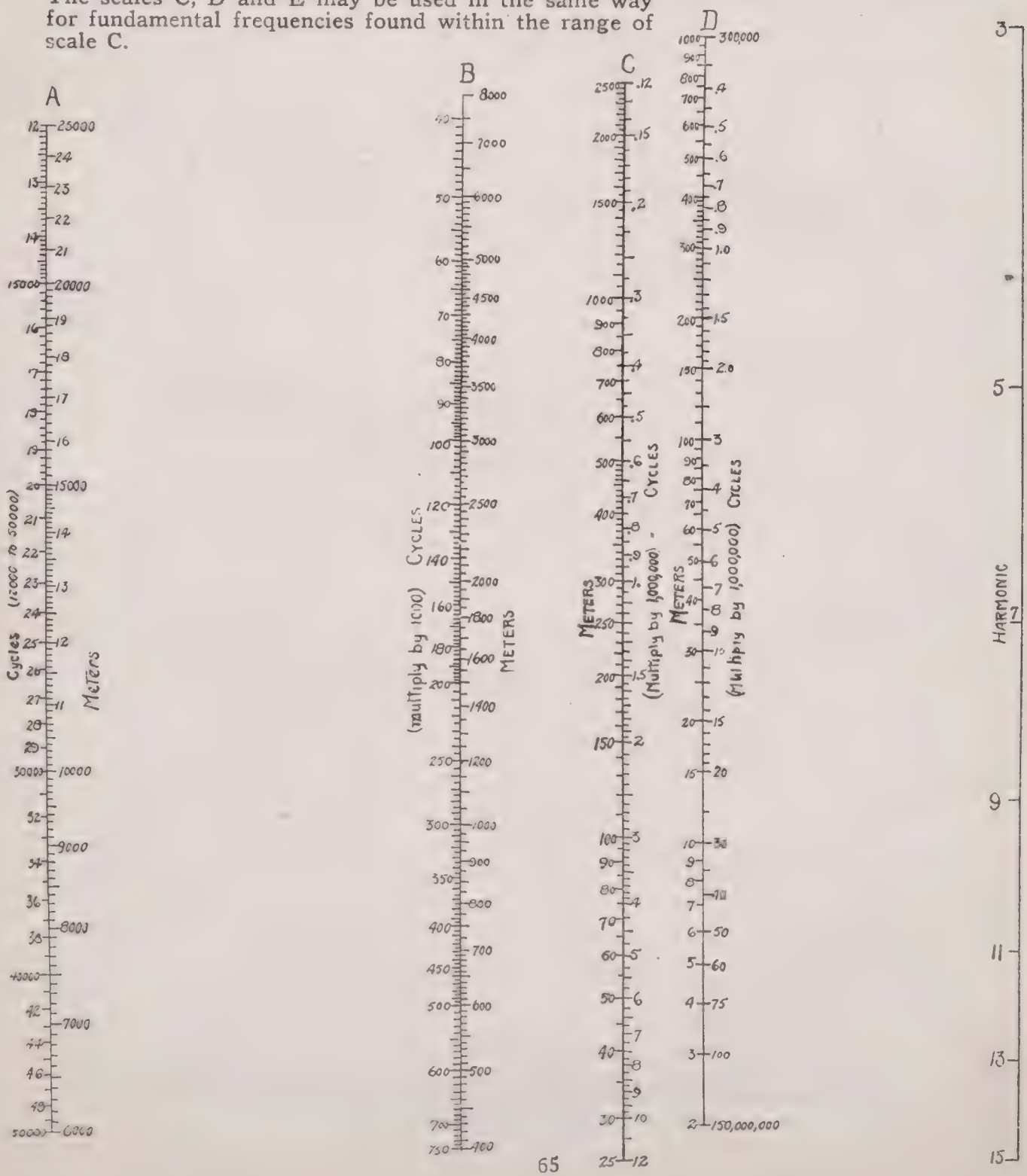
Wavelength and Frequency

THE relation between the wavelength and frequency values, for waves between 2 and 25,000 meters, is shown on the chart below. Here each scale may be used independently as the frequency corresponding to any wavelength is found on the opposite side of the line from that wavelength value.

For wavelengths between 6,000 and 25,000 meters use Scale A.
For wavelengths between 400 and 6,000 meters use Scale B.
For wavelengths between 25 and 400 meters use Scale C.
For wavelengths below 25 meters use Scale D.

Determination of Upper Harmonics

TO find the value of any harmonic (odd) between the third and fifteenth, operate as follows: If the fundamental frequency is found on scale A, a line from that point to the position of the desired harmonic on scale E will intersect scale B and indicate the frequency of the harmonic selected. Similarly, if the fundamental is found on scale B the harmonic is indicated on scale C, using the same method of operation. The scales C, D and E may be used in the same way for fundamental frequencies found within the range of scale C.



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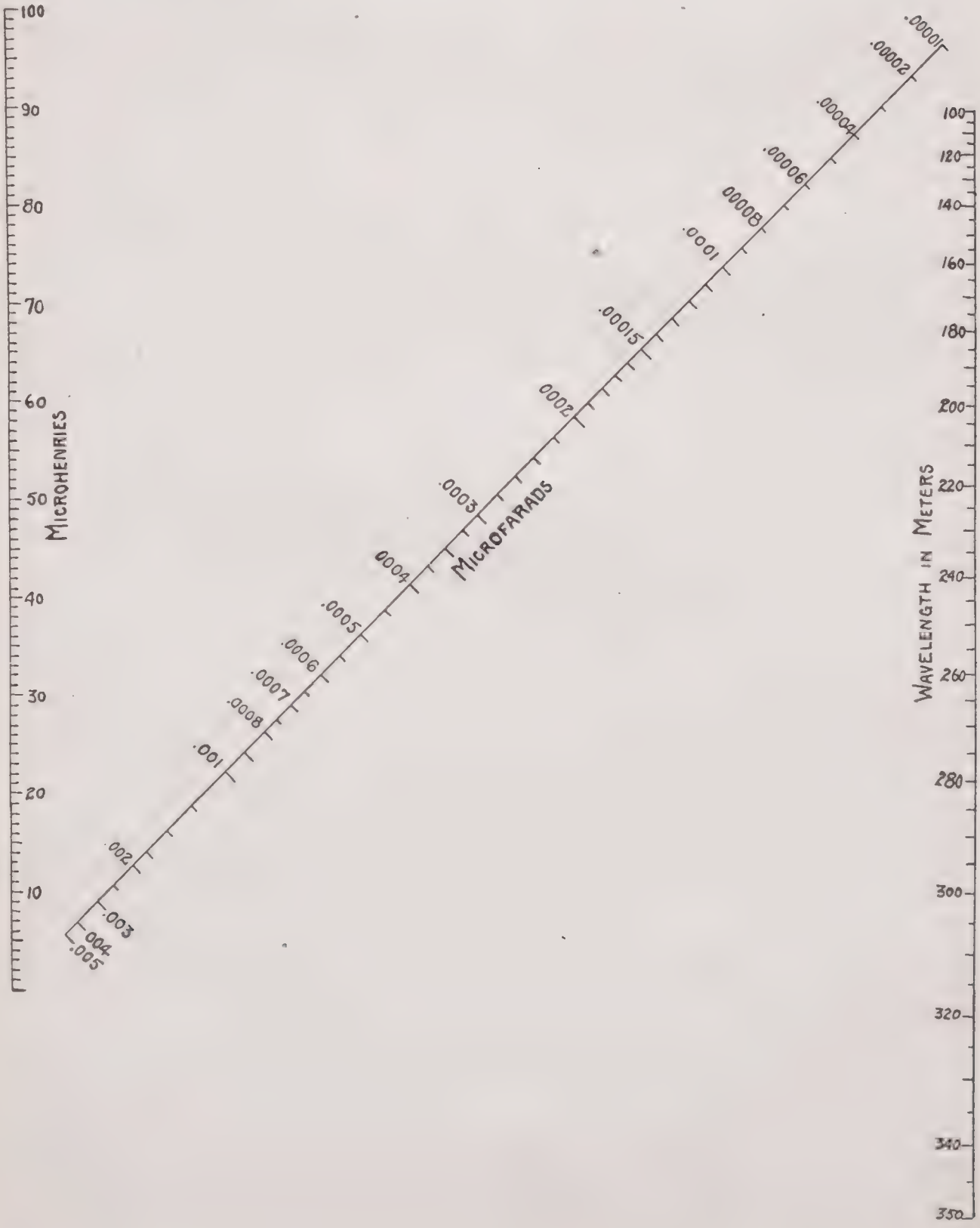
Wavelength Chart—100 to 350 Meters

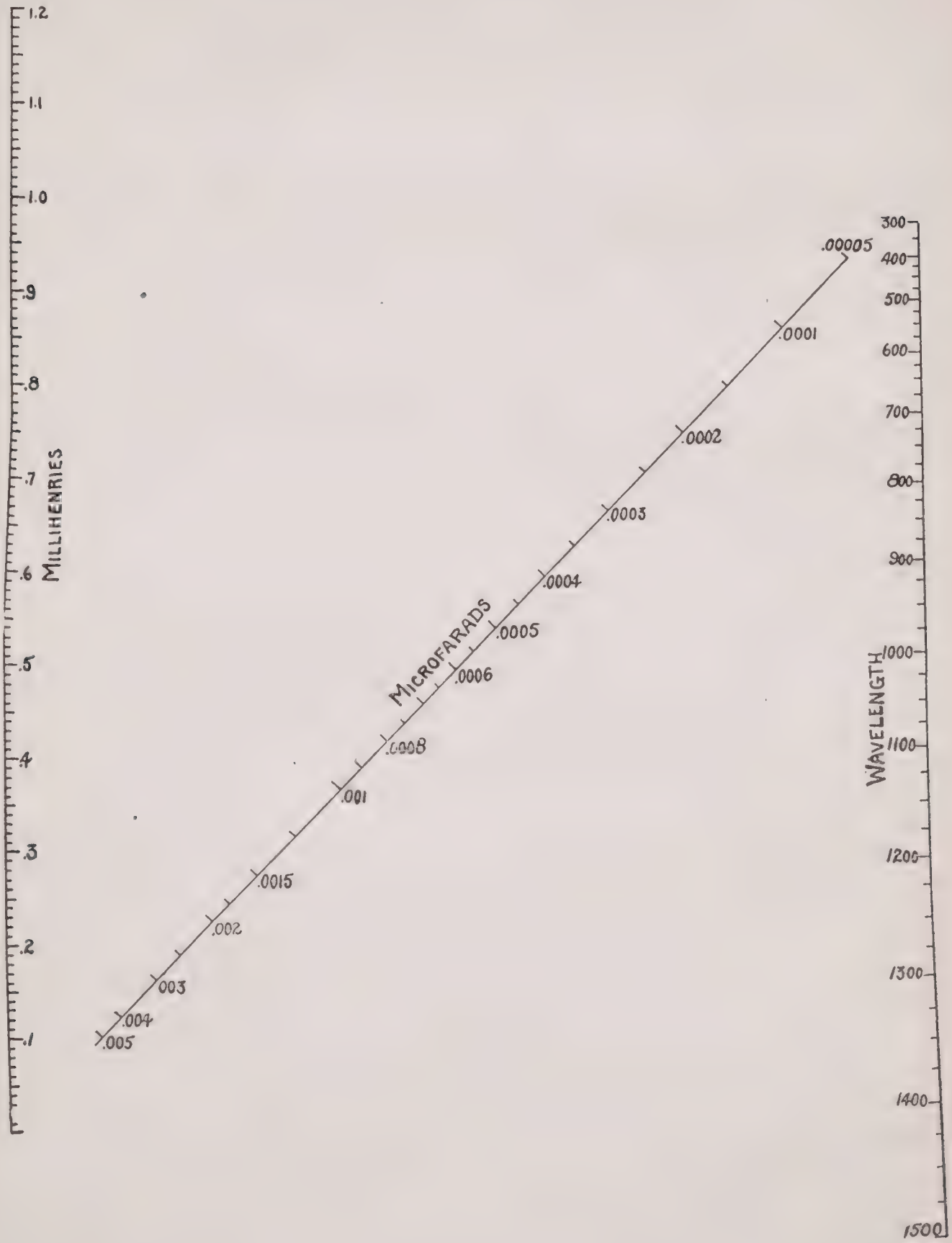
THE wavelength produced by given values of inductance and capacity can be determined on the chart below or on one of those immediately following. The first scale is graduated with the unit of inductance of microhenries. The center (oblique) scale in microfarads and the wavelength scale in meters.

If it should happen that the value of inductance should be beyond the inductance scale, multiply all values on that scale by 10 and divide the values on the capacity scale by 10 and use as before.

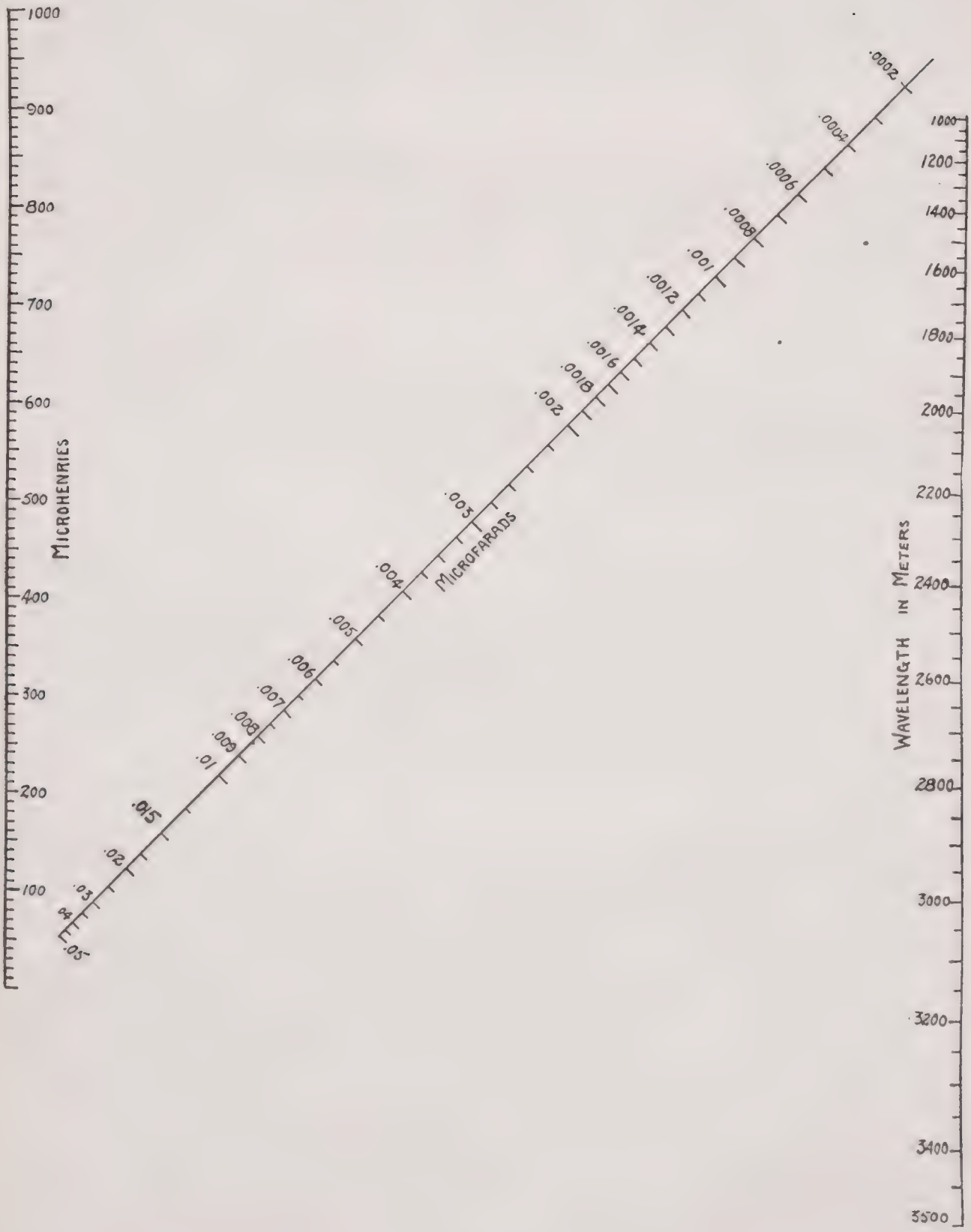
The charts may be used in a variety of ways, such as solving for inductance or capacity, when the other factors are known.

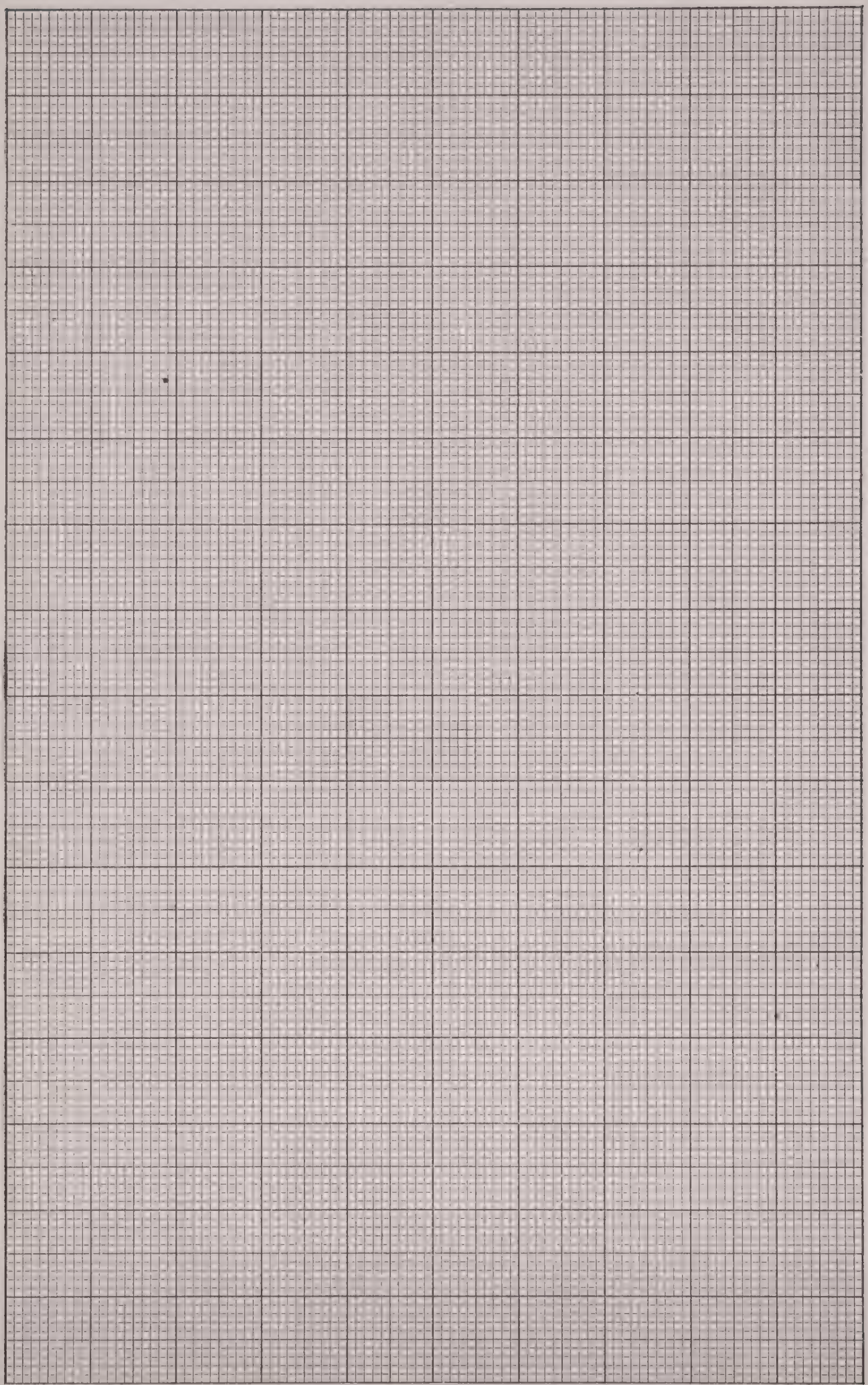


Wavelength Chart—350 to 1,500 Meters

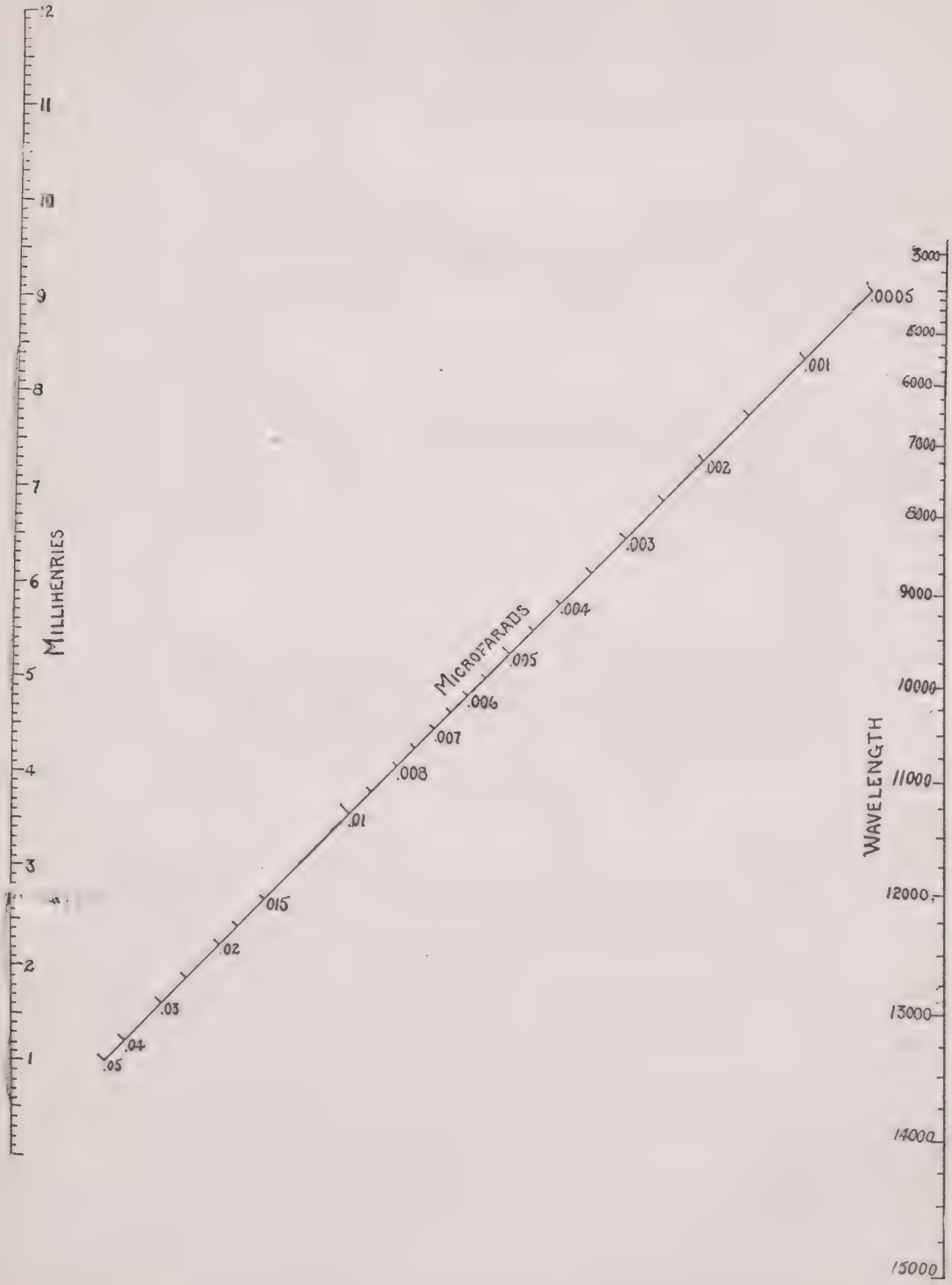


Wavelength Chart—1,500 to 3,500 Meters





Wavelength Chart—3,500 to 15,000 Meters



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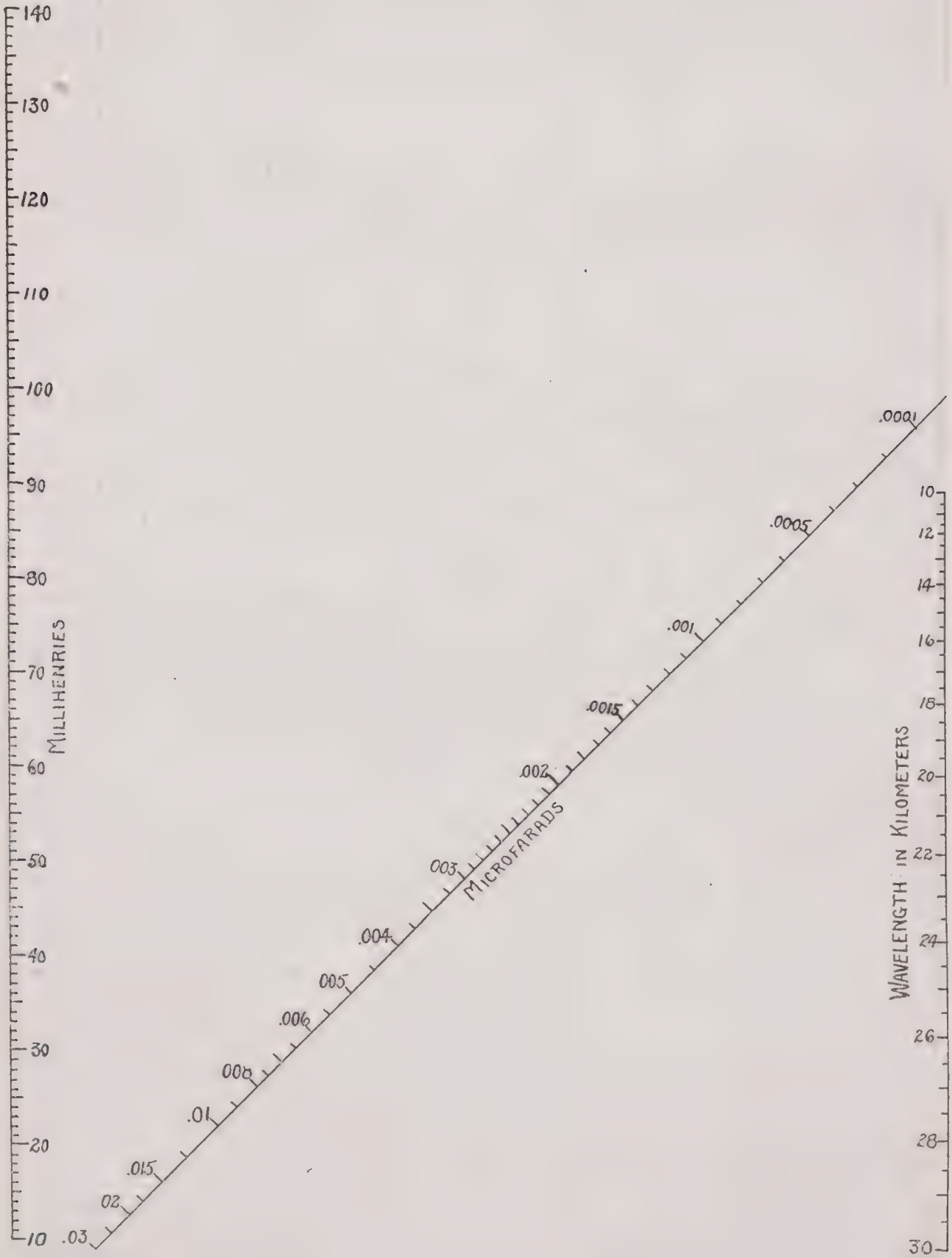
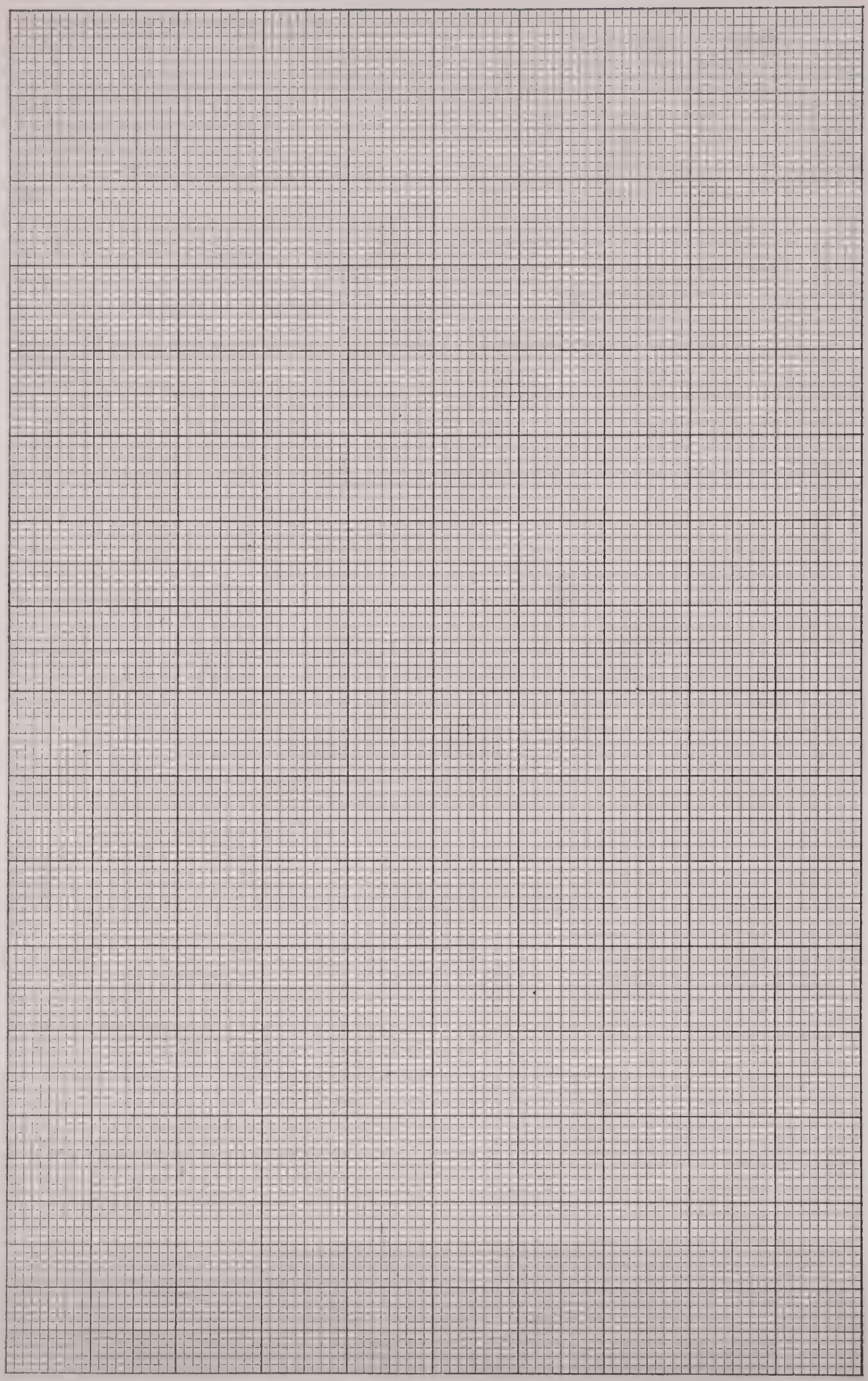
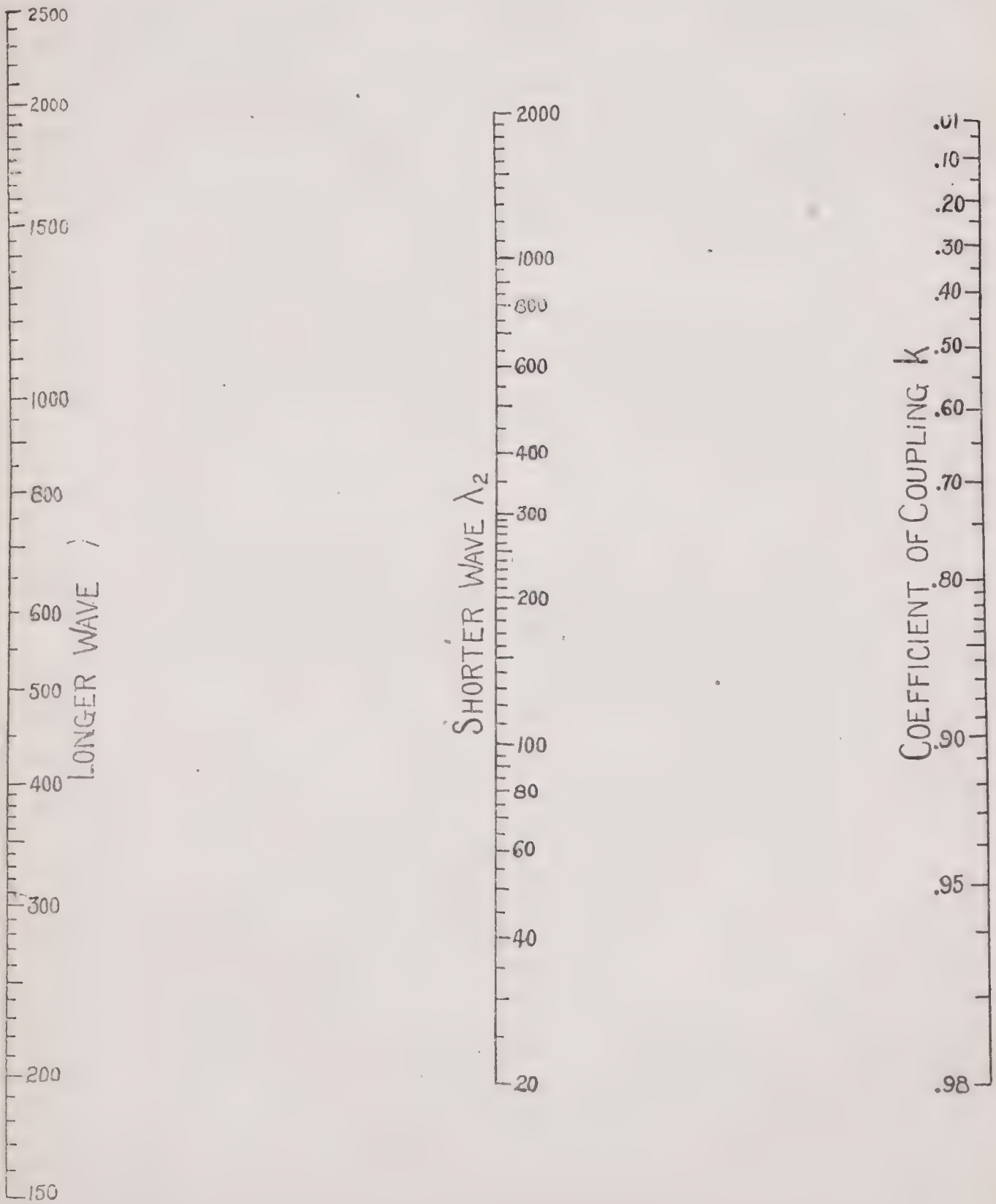
Wavelength Chart—15,000 to 30,000 Meters





Determination of the Coefficient of Coupling

WHEN the coefficient of coupling (electromagnetic) between two circuits is greater than zero two waves will be present in the system. If λ_1 is the longer of these waves (in meters) and λ_2 is the shorter, the coefficient may be determined from the following chart. It is assumed that each circuit is separately resonant to the same wavelength.



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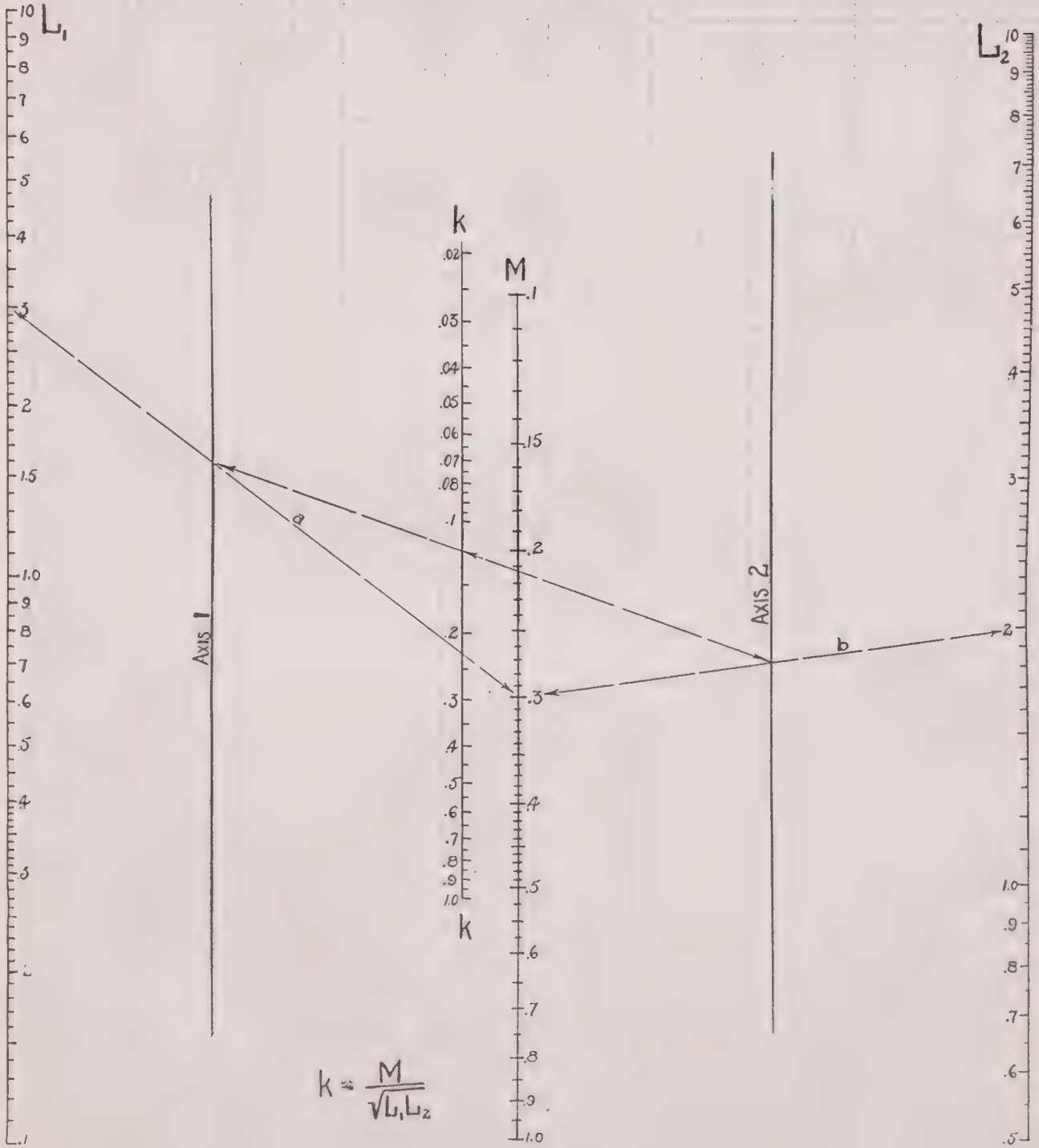
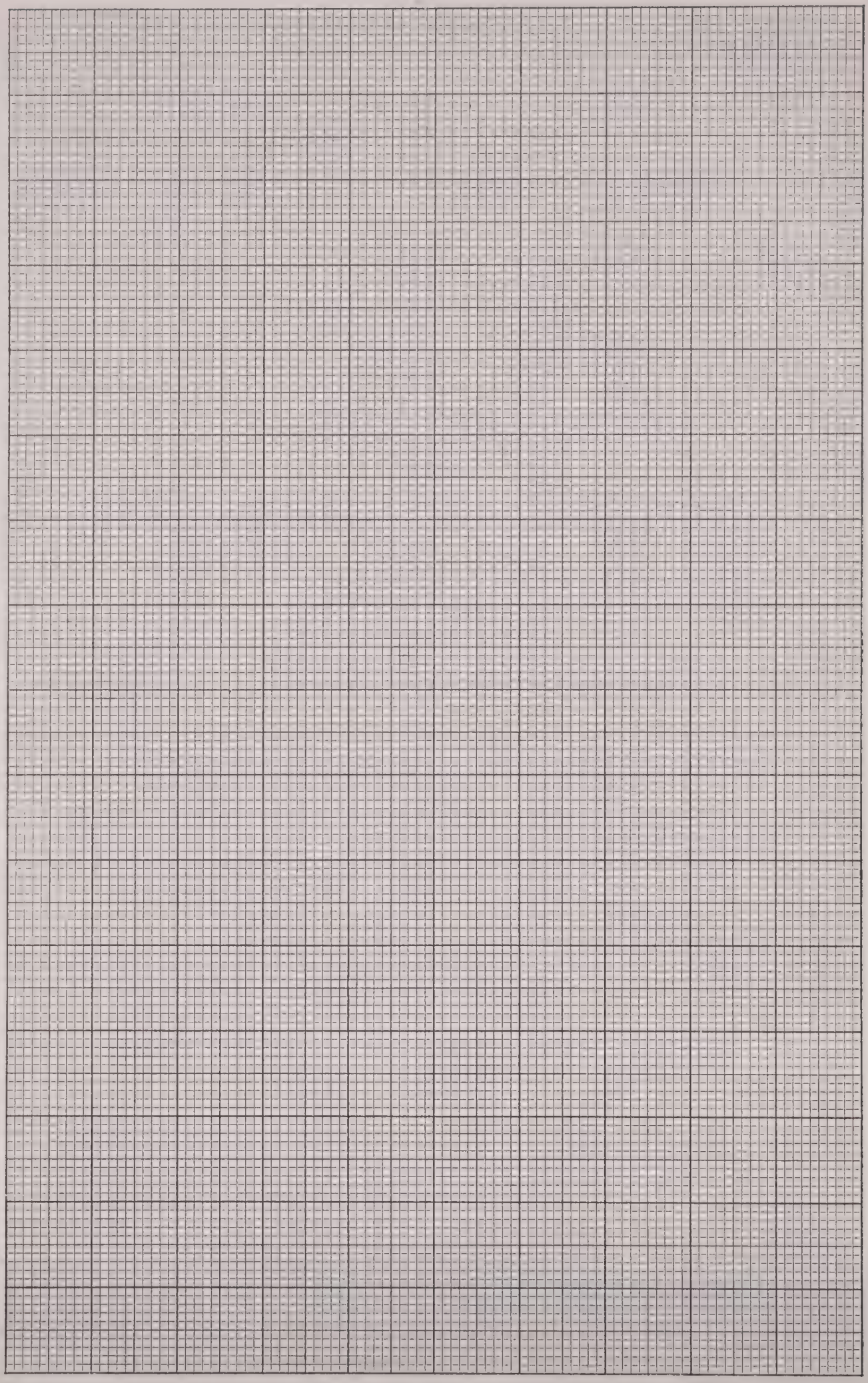
Coefficient of Electromagnetic Coupling

TWO circuits containing inductances L_1 and L_2 are coupled by the mutual inductance M between the coils. The inductances may be measured in any units if the same unit is used for all three values. The coefficient of coupling may be determined using the same method as in solution below.

Suppose L_1=3 millihenries, L_2=2 millihenries and M=.3 millihenry. The latter value is located on the center scale and two lines are constructed to the scales L_1 and L_2 (see keys "a" and "b"). A third line is constructed connecting the points where the key lines intersect with the Axis lines. Where the latter line crosses the K scale (at .125 for the solution shown) the value for the coupling coefficient is shown.

The formula on which the chart is based is given below. For other values of inductance each scale may be multiplied by a multiple or submultiple of 10.





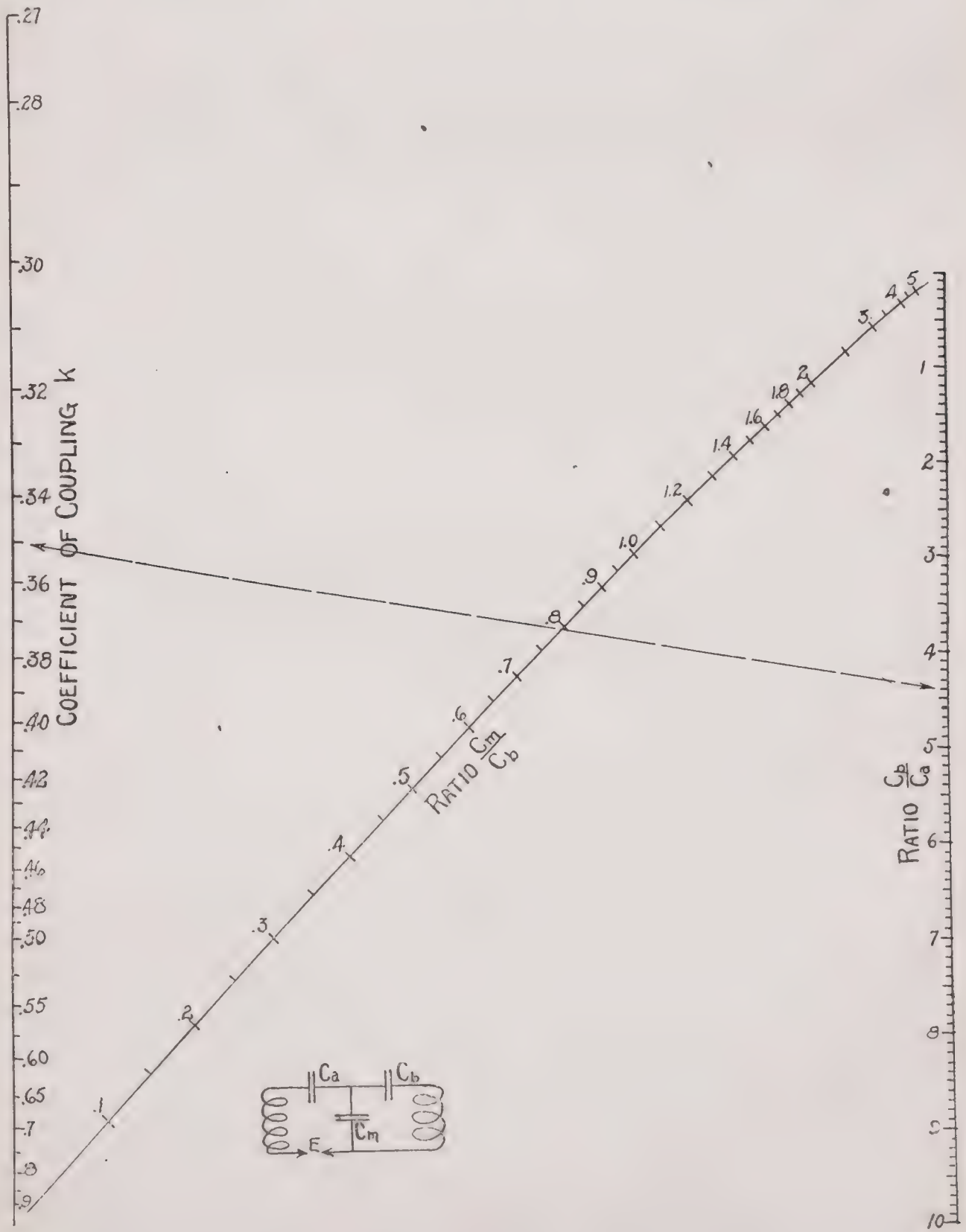
Coefficient of Electrostatic Coupling

THE circuit considered is given below. The values for C_a and C_b may be interchanged if C_a happens to be larger than C_b.

The solution indicated is for the following problem:

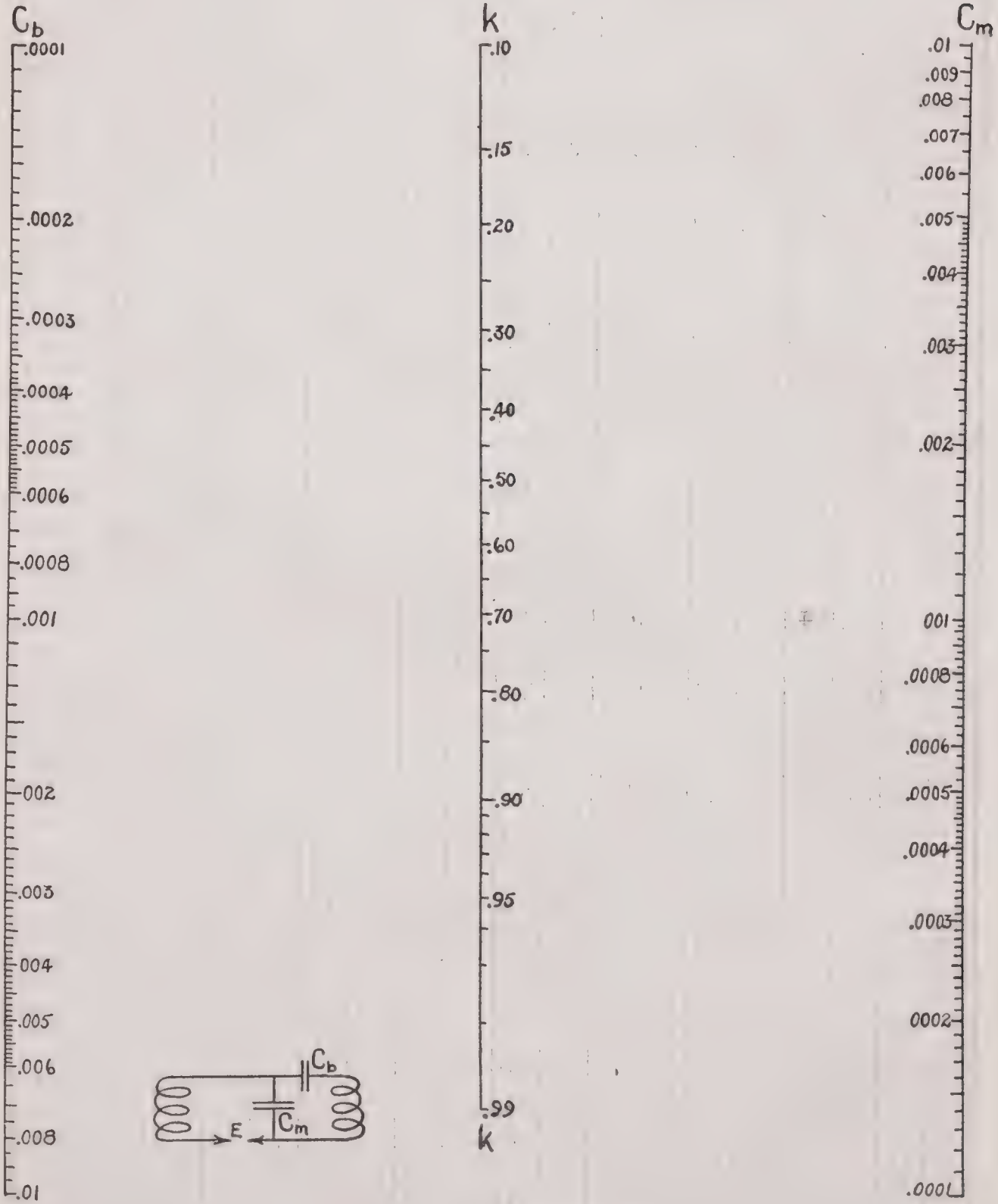
C_a=.0002; C_b=.00088 and C_m=.0007 (all microfarads).

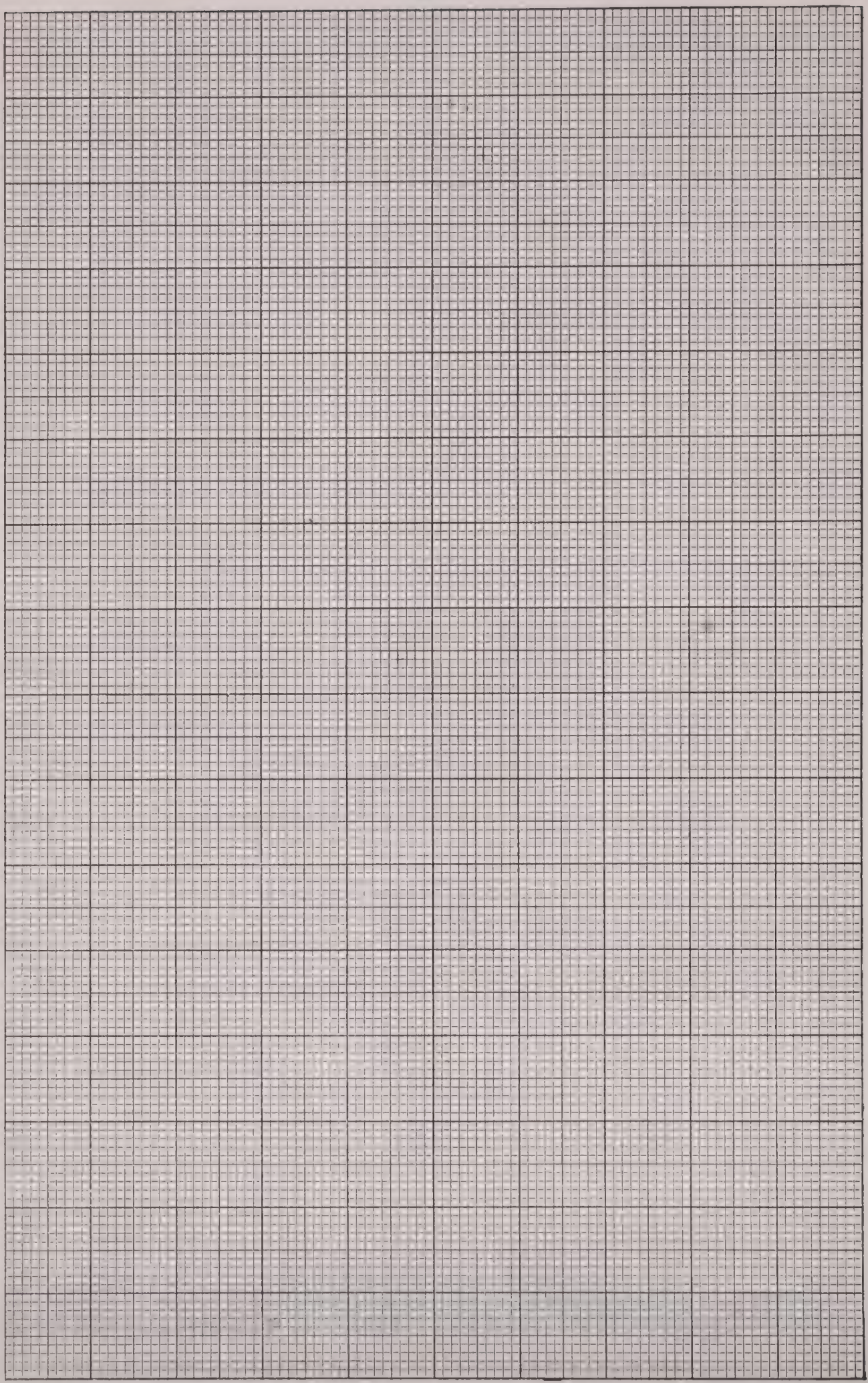
The ratio of C_b to C_a=4.4, and the ratio of C_m to C_b=.795. Locating these points of the scales and extending a line through them to the "K" scale gives K=.35.



Coefficient of Electrostatic Coupling

THE circuit considered is given below. The capacity scales represent microfarads (or any other unit, if desired, provided the same unit is applied to both scales). The coefficient of coupling is found on the center scale.

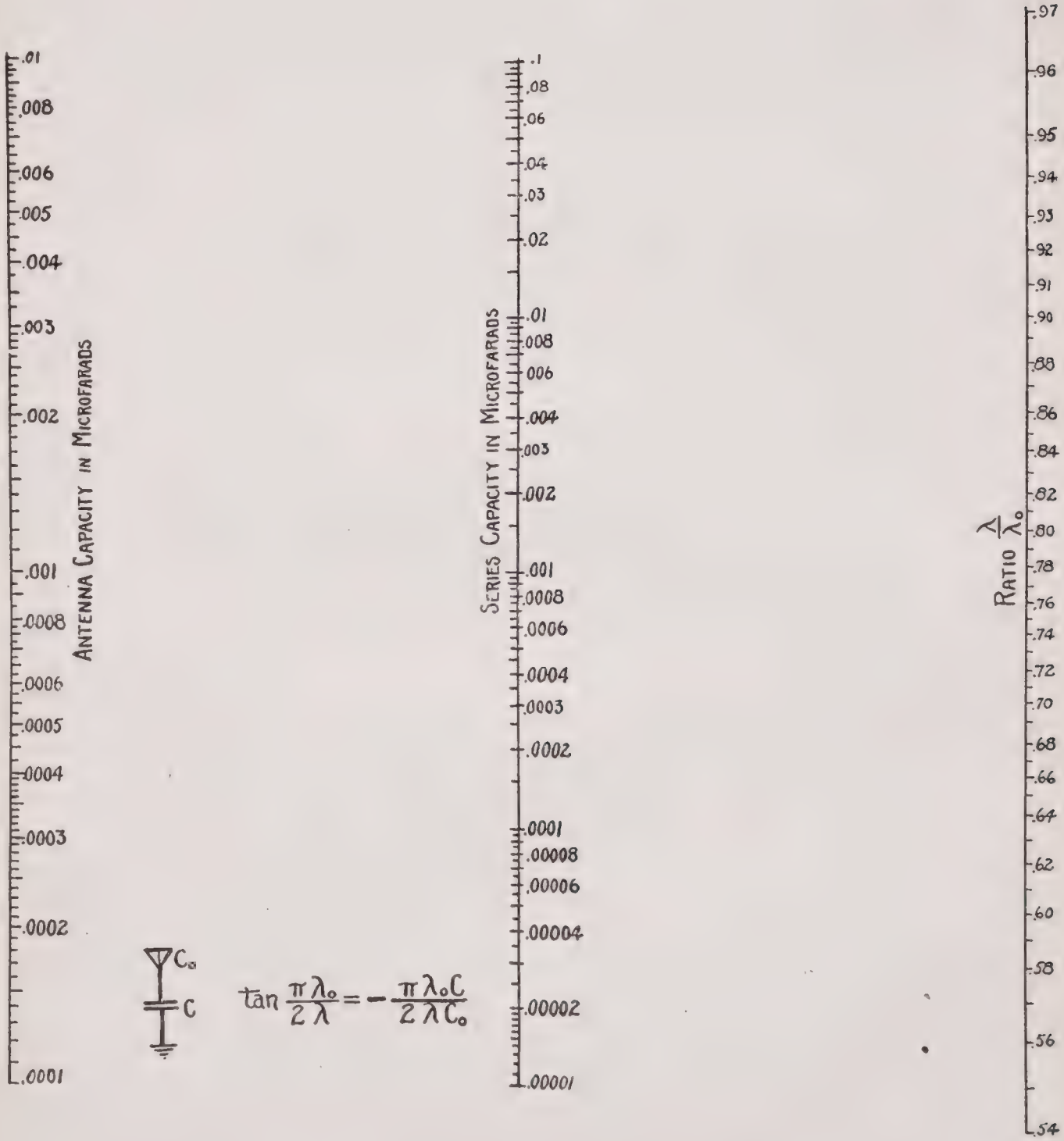




Effect of a Series Condenser Upon the Fundamental Wavelength

THE effect of a series condenser in lowering the natural wavelength of an antenna circuit may be determined with the following chart. This chart is based on the formula given below:

The method of operation is the same as previous charts. The ratio scale may also be interpreted in percent of fundamental wavelength if desired.



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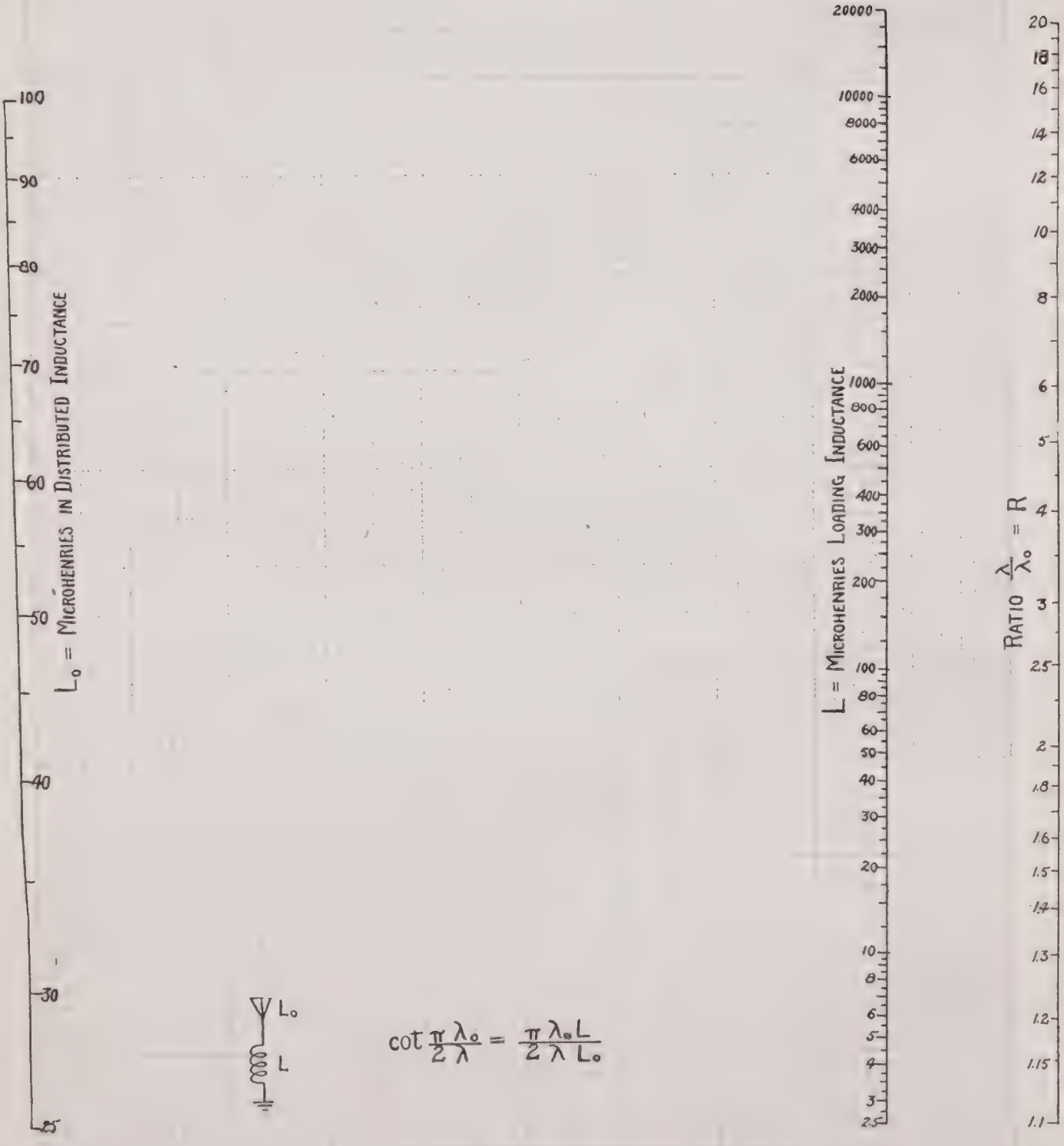
Effect of a Loading Inductance Upon Fundamental Wavelength

THE wavelength of an antenna may be increased by the application of an inductance in series with the circuit. Due to the distributed nature of the inductance of the antenna the total inductance is not equal to the sum of the two inductances.

The effect of such loading may be determined by the chart, which is based on the theoretical formula below.



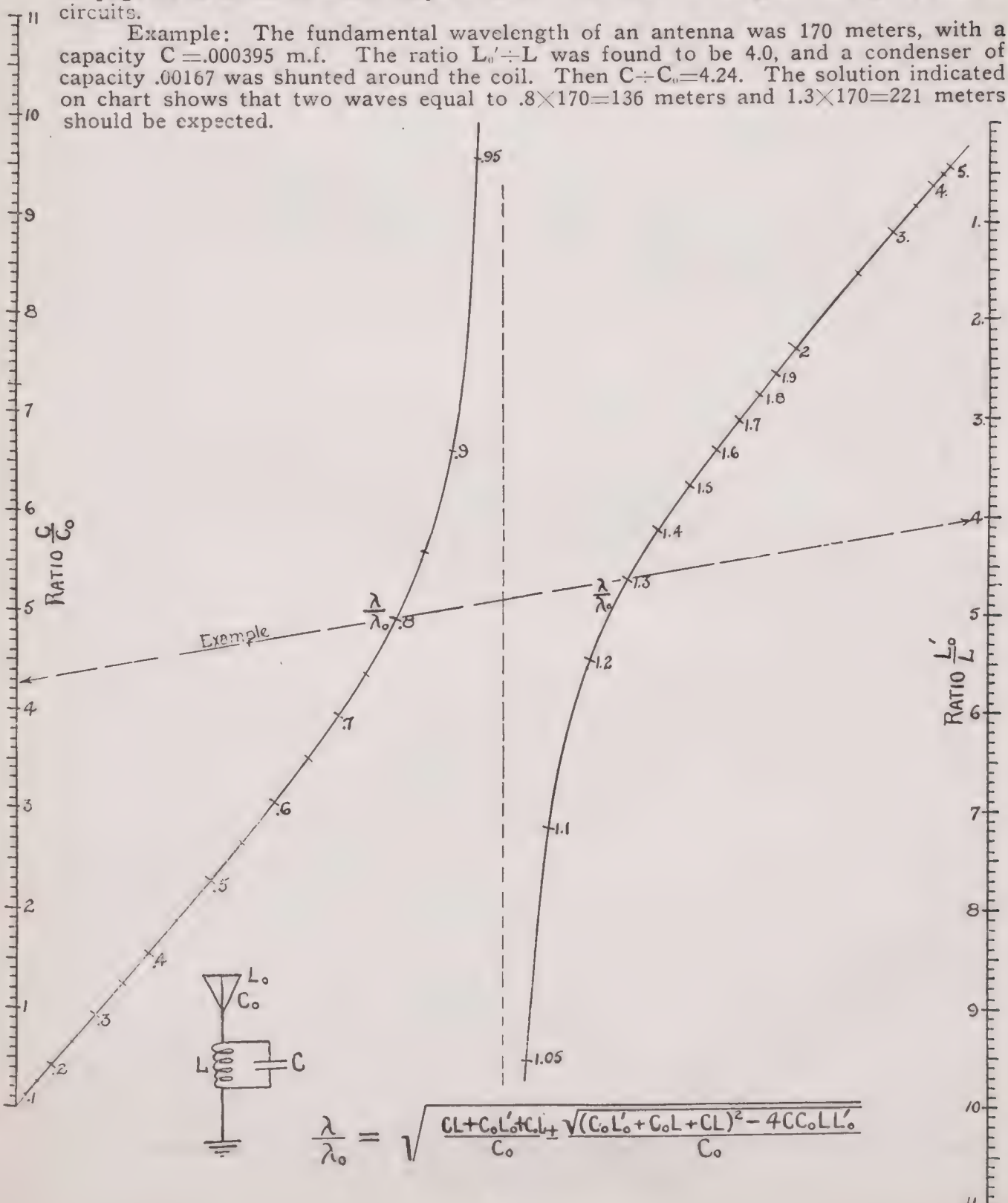
Effect of a Parallel Condenser on Antenna

IN general the effect of such a circuit (see schematic diagram below) is to enable the antenna circuit to respond to two waves at the same time, one below and the other above the fundamental of the antenna. These waves depend upon the ratio of the capacity of the condenser at the base to that of the antenna, and upon the ratio of the effective inductance of the antenna to the inductance of the loading coil.

When these ratios are applied to the respective scales a line between those points will cross the two curved scales at points that indicate the wavelengths to which the circuit will respond. These wavelengths are compared on the scales to the fundamental wavelength of the antenna. The formula upon which the chart is based is given below.

The ratio of effective inductance of the antenna to the loading inductance must be used in each instance. The effective antenna inductance is in general about one-third of the inductance for uniform currents. To assist in determining this ratio the chart on page 93 is included, which may be used. This chart is designed for lightly loaded circuits.

Example: The fundamental wavelength of an antenna was 170 meters, with a capacity $C = .000395$ m.f. The ratio $L_o' \div L$ was found to be 4.0, and a condenser of capacity .00167 was shunted around the coil. Then $C \div C_o = 4.24$. The solution indicated on chart shows that two waves equal to $.8 \times 170 = 136$ meters and $1.3 \times 170 = 221$ meters should be expected.



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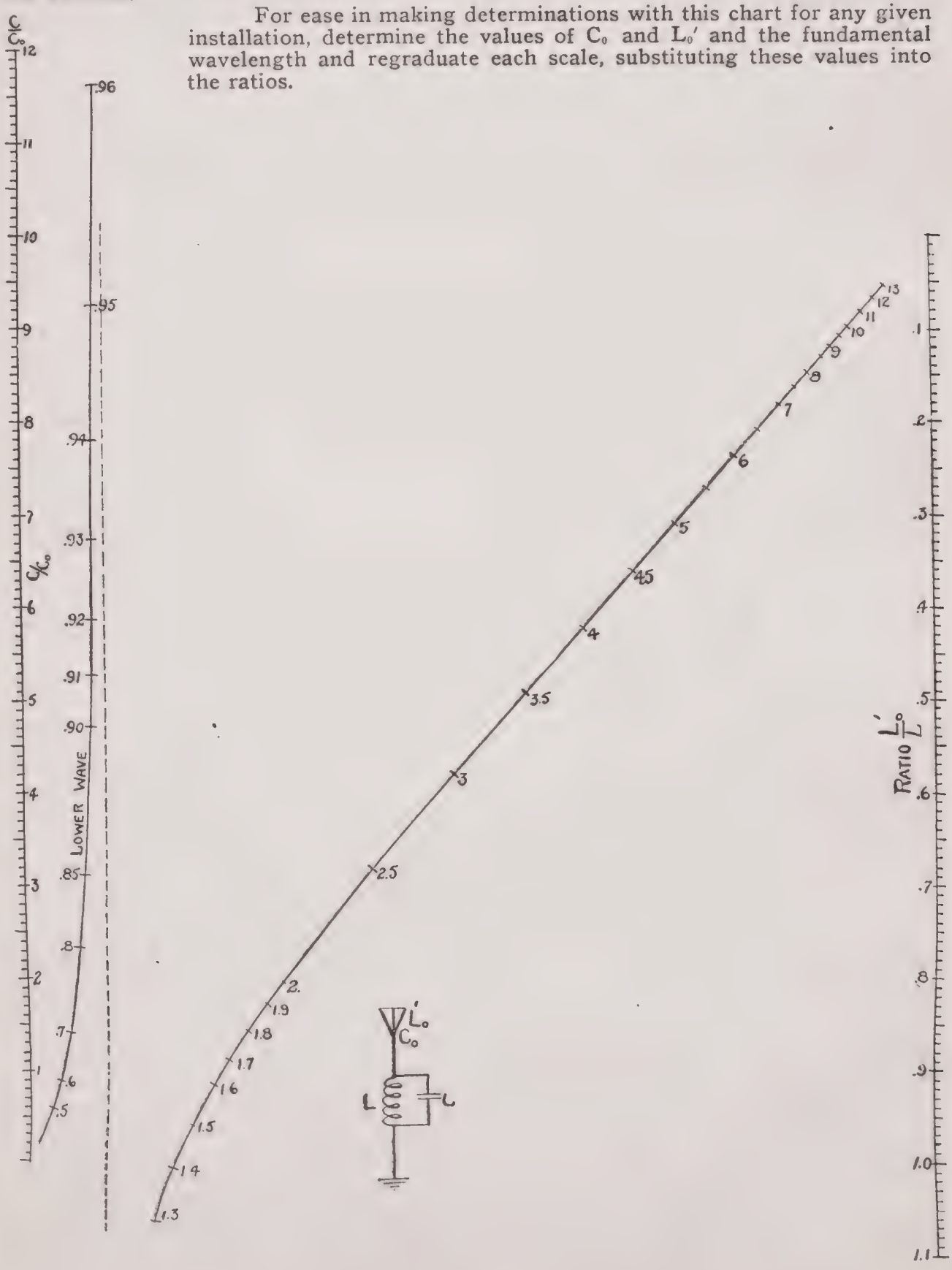
Effect of a Parallel Condenser on Heavily Loaded Antenna

THIS chart is similar to the preceding and the same rules apply. It can be used to greatest advantage in cases where the loading inductance is one to ten times the effective antenna inductance.

It is to be noted that in this circuit it is impossible to adjust the values so that the circuit will be exactly in tune with a wave equal to the fundamental wavelength of the antenna.

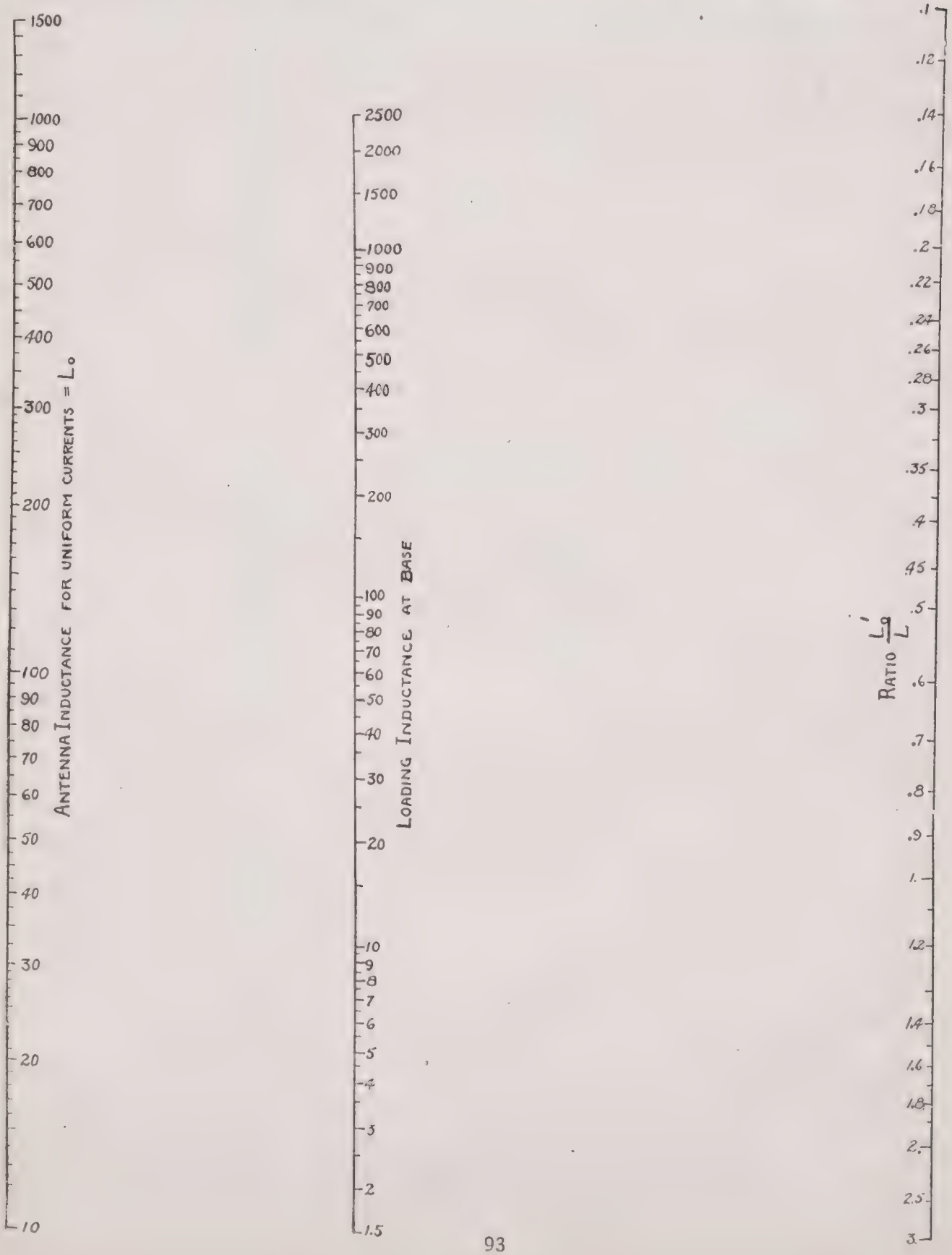
For ease in making determinations with this chart for any given installation, determine the values of C_0 and L_0' and the fundamental wavelength and regraduate each scale, substituting these values into the ratios.



Determination of Ratio of Effective Antenna Inductance to Loading Inductance

ALL of the inductance of an antenna measured with uniform currents is not effective, due to its distributed nature. The value of the ratio of the effective inductance of an antenna to the loading inductance is given at the right, after having selected points on the other two scales to correspond to the values in the problem.

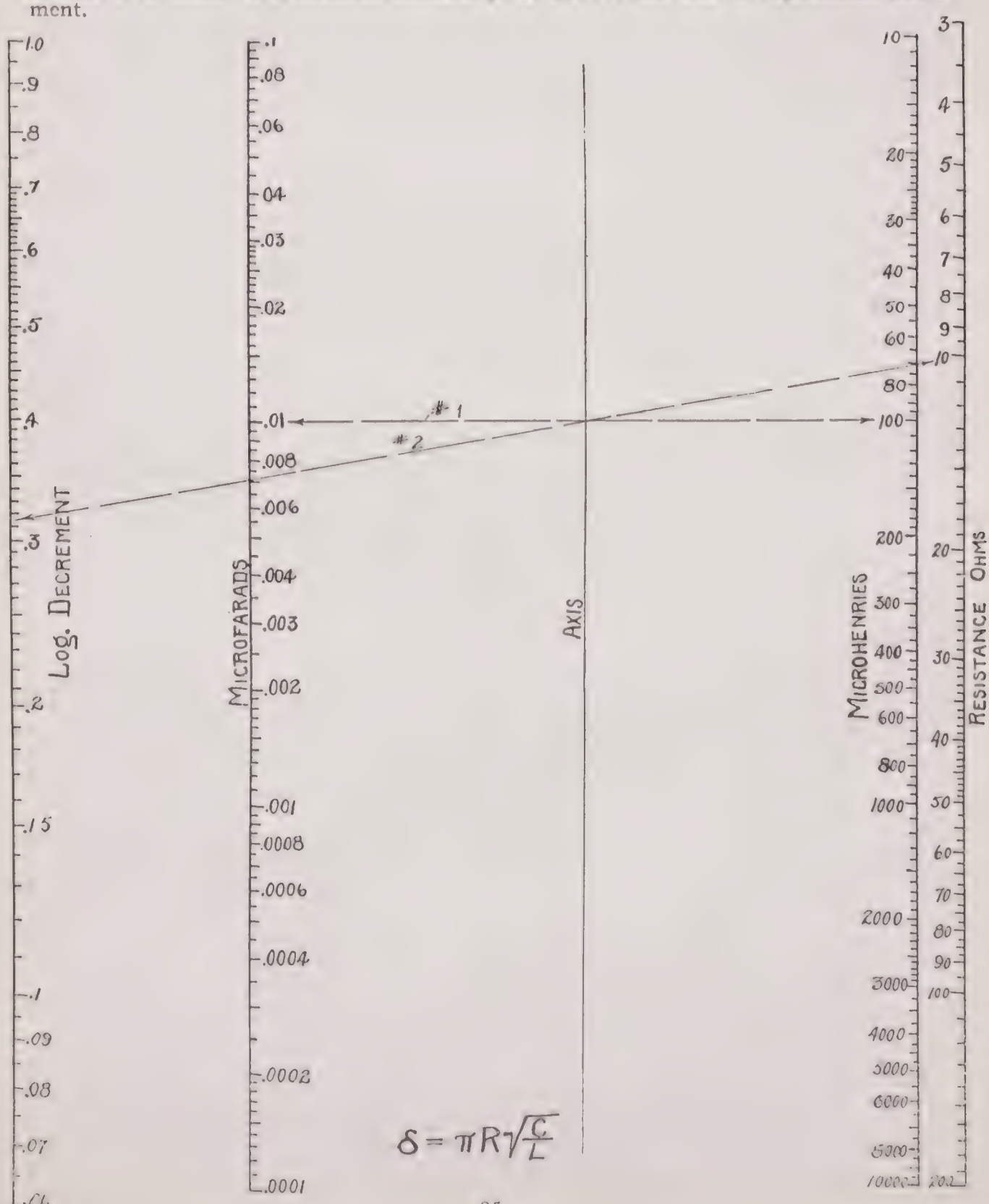
This chart is particularly designed for determining values of the inductance ratio scales on the two preceding charts. The units for the scales may represent any unit of inductance desired or may be taken to represent microhenries for nearly all problems.



Decrement of a Closed Oscillatory Circuit

THE formula below gives the value of the logarithmic decrement of an oscillatory circuit. This may be solved with the chart as follows: Select on the microfarads and microhenries scales points that represent the values of capacity and inductance respectively in the circuit under consideration. Determine where a line between these points will cross the axis. Select a point on the resistance scale to equal the high frequency resistance in ohms, and from the latter point, a line is run to intersect with the axis at the same point as before. Extend this line to the decrement scale. The solution is found where the line intersects with the latter scale.

The solution indicated is: The inductance and capacity of a certain circuit are 100 microhenries (0.1 millihenry) and .01 microfarads respectively (key 1). The resistance is 10 ohms. The solution indicated gives .315 for the value of logarithmic decrement.



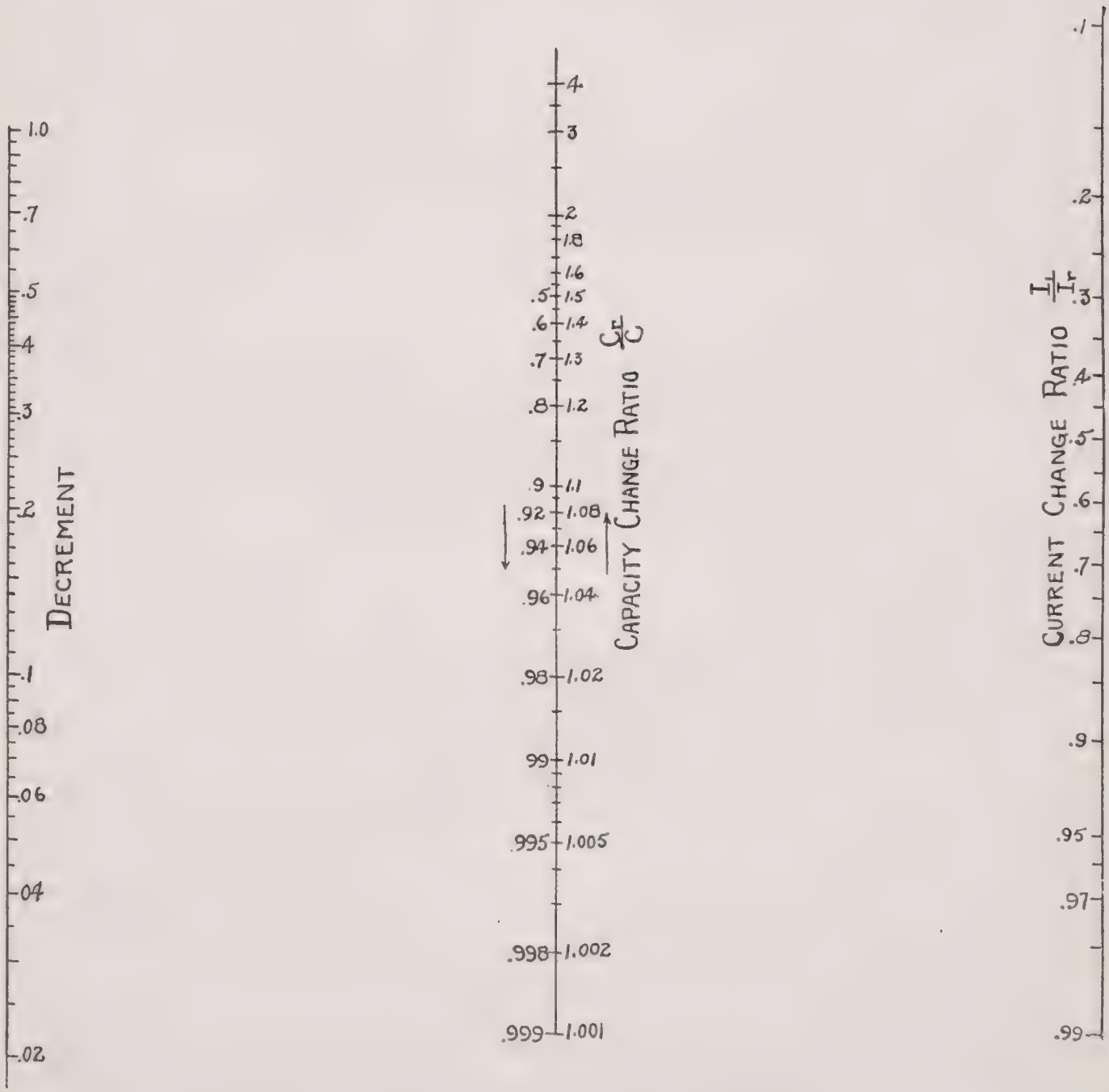
Solution of Bjerknes' Formula for Logarithmic Decrement

DETERMINE the capacity change ratio necessary to produce a given current change, by means of a wavemeter and an ammeter and locate these values on the respective scales. A straight-edge laid across the scales at these points will intersect the decrement scale at the value of the decrement of the circuit, plus that of the wavemeter.

The formula of Bjerknes, upon which the chart is based, is not accurate, however, for large values of decrement, so that a value on the upper end of this scale only approximates true conditions.

The subscript r denotes the current or capacity at the resonance point.

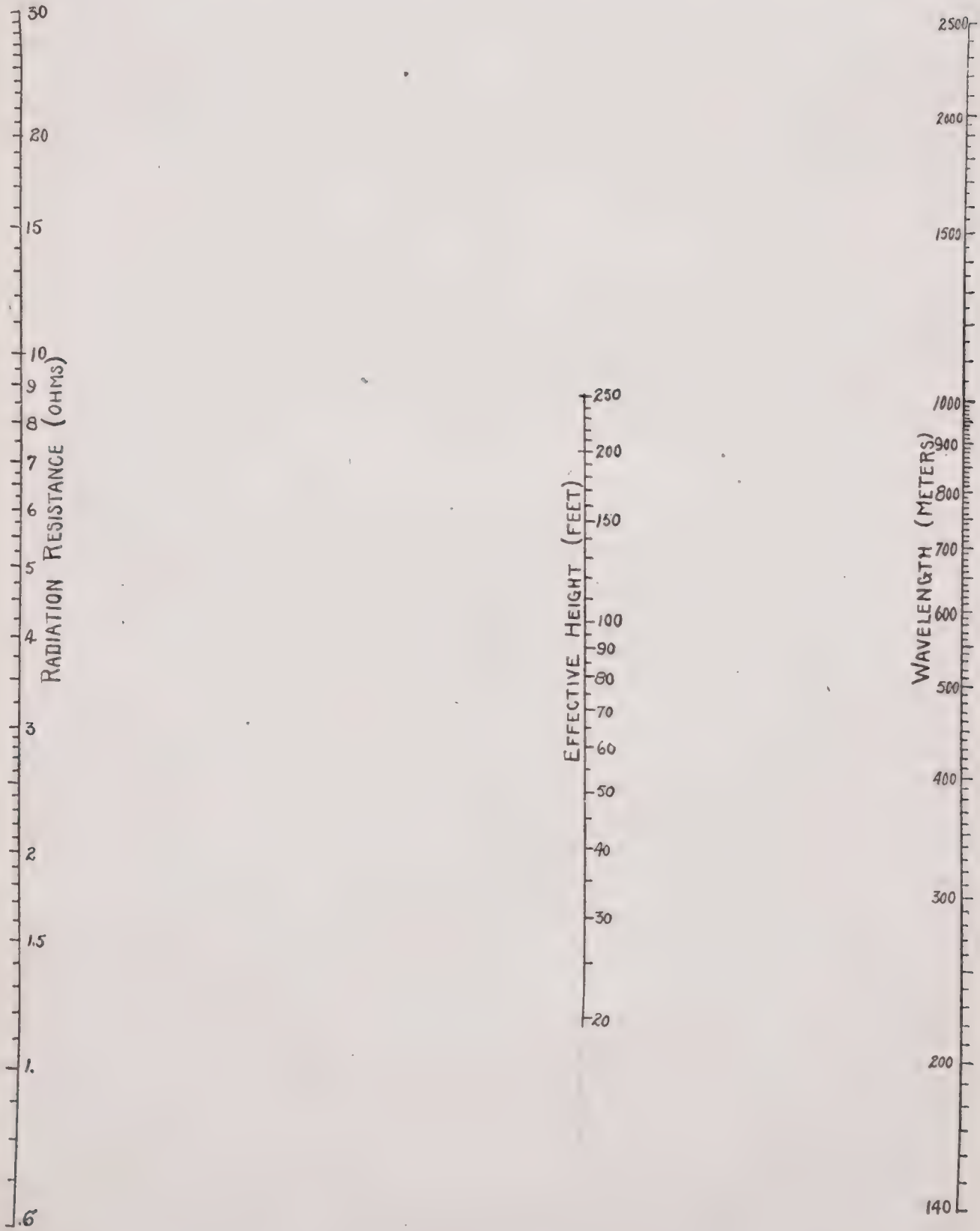
Since the capacity may be varied in either direction from the resonance point, the center scale is graduated to indicate both conditions.

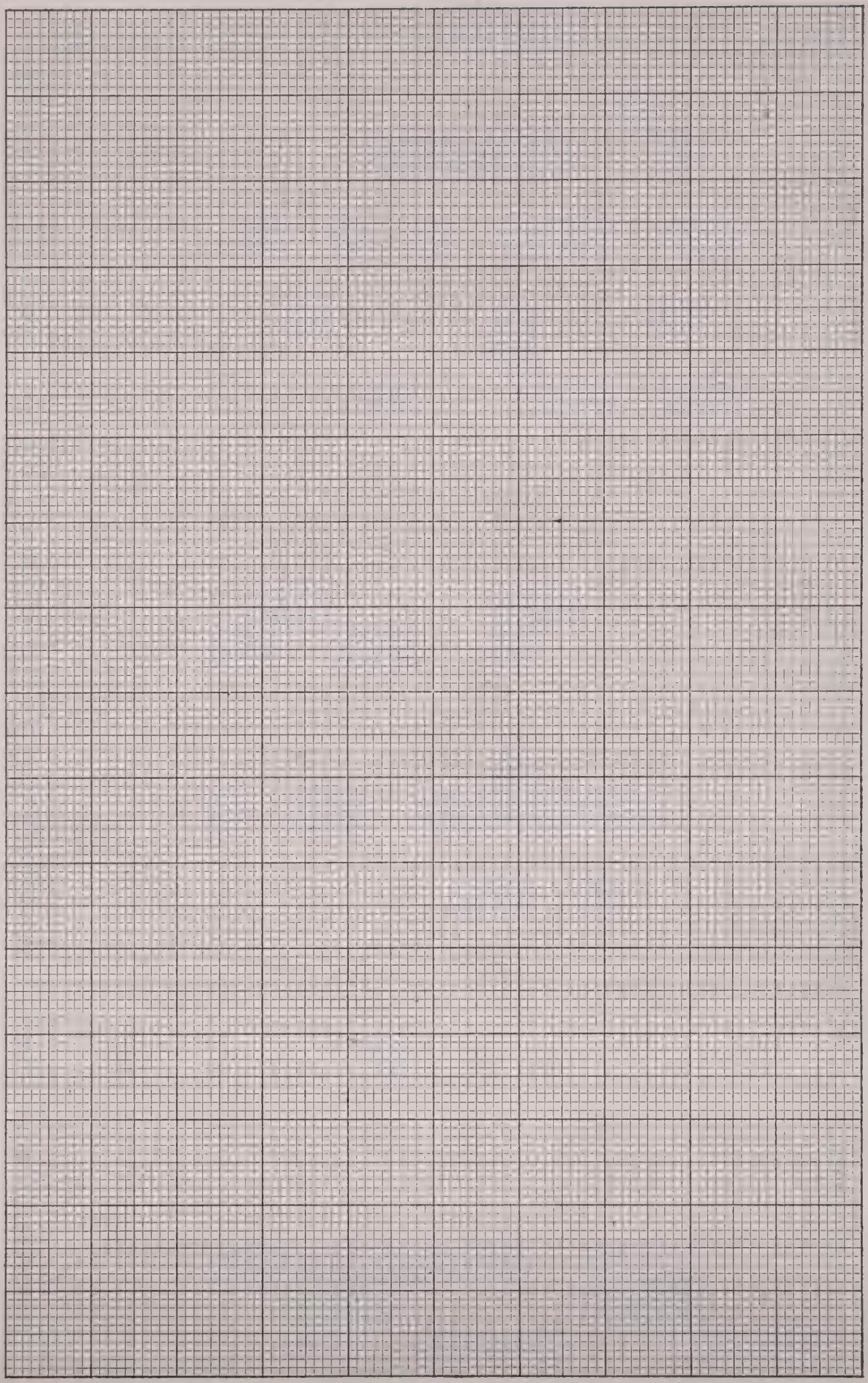


Radiation Resistance of an Antenna

THE radiation resistance of an antenna is proportional to the square of the effective height and inversely proportional to the square of the wavelength. This relation furnishes the basis for the following chart, by which the radiation resistance in ohms may be found for any ratio of height to wavelength.

To determine the effective height of an antenna use chart on page 101.





Effective Height of an Antenna

THE effective height is equal to the actual height multiplied by the form factor. The latter is found on scale to the right, where it is intersected by a line cutting the other two scales at points representing the height and length respectively. The form factor of a vertical antenna is .637.

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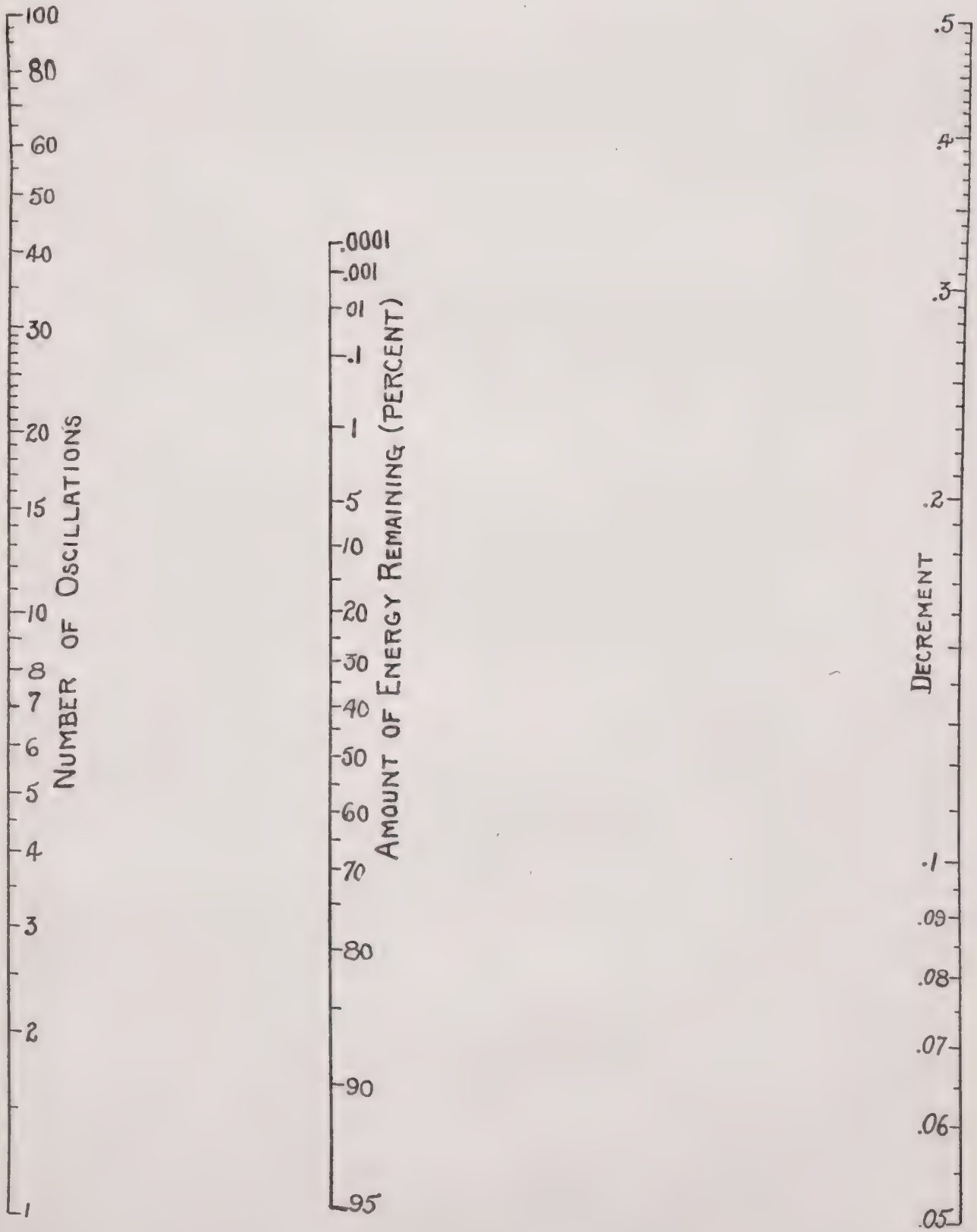
Energy in an Oscillating Circuit Containing Damping

THE amount of energy remaining in an oscillating circuit after a certain number of oscillations depends upon the logarithmic decrement. The percent of energy found in a circuit (compared to the initial amount) after any number of cycles for a given decrement may be determined with the chart below. A straight-edge laid across the scales will indicate points on each scale that will fit a solution.

The chart may be used also to determine the number of oscillations that will take place before the energy has decreased a given amount with a certain decrement. The decrement refers to decrement per complete cycle.

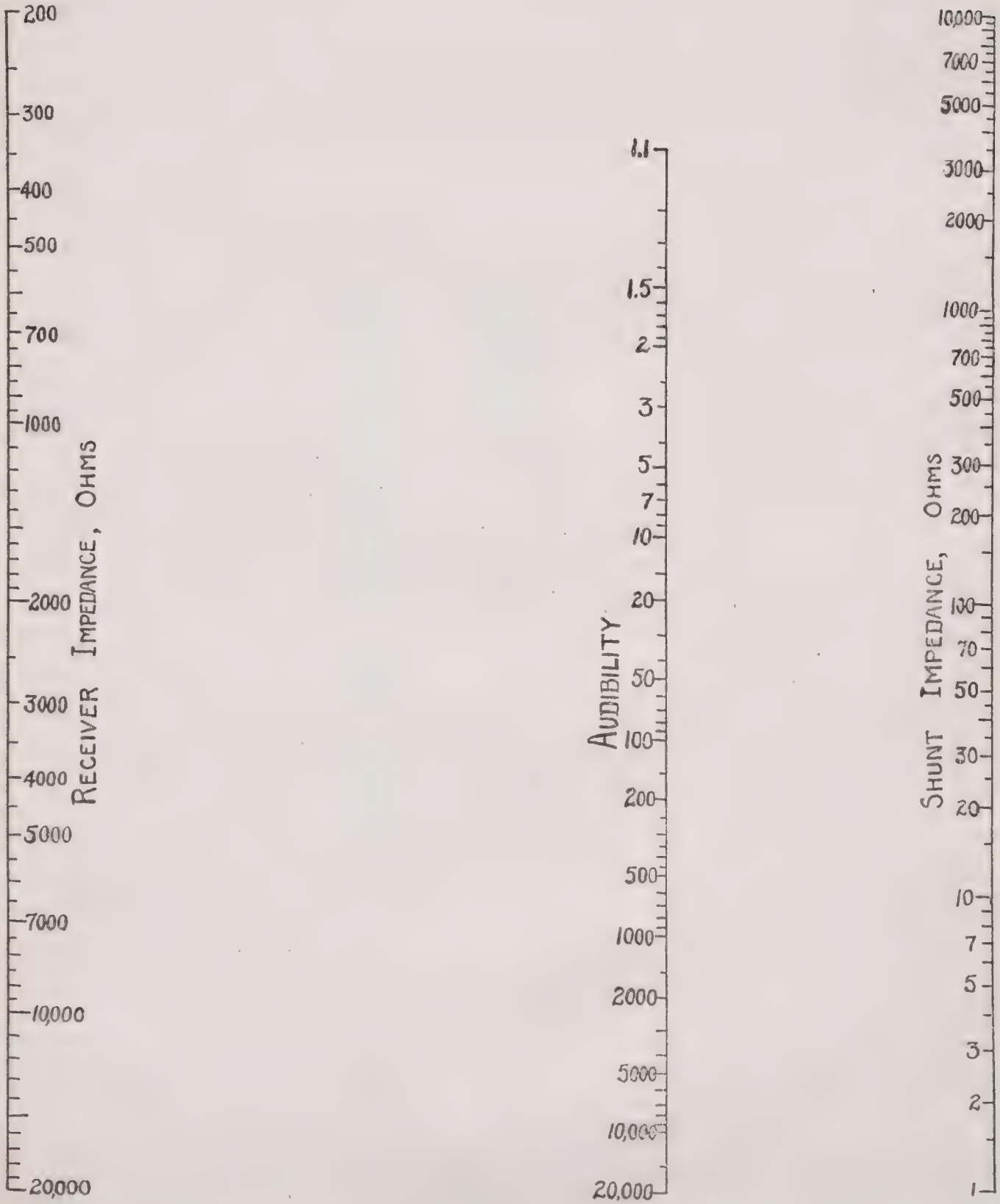


Audibility

A COMMON method of referring to signal intensity is to its audibility. The audibility is determined by measuring the impedance of a shunt placed across the receivers that will make the intensity of the signal just inaudible. Values of shunt impedance and receiver impedance are located on respective scales and a straightedge laid across these points will cross the center scale at the value of the audibility.

For rough approximation resistance values of the receiver winding and the shunt are used instead of their impedance value.

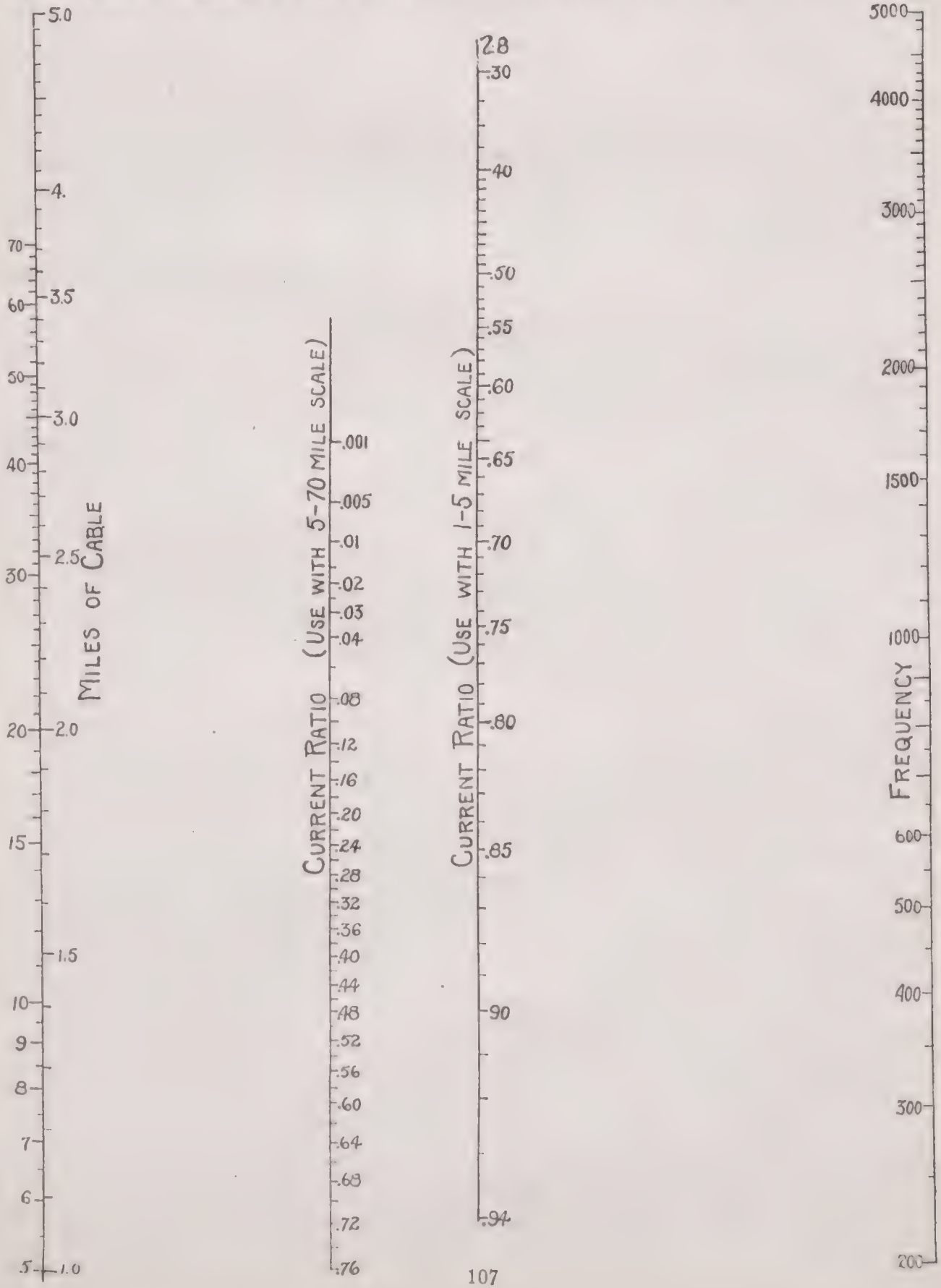
For special receivers, which have impedances over 20,000 ohms, multiply values on the receiver, and shunt impedance scales by 10, leaving audibility scale unchanged.

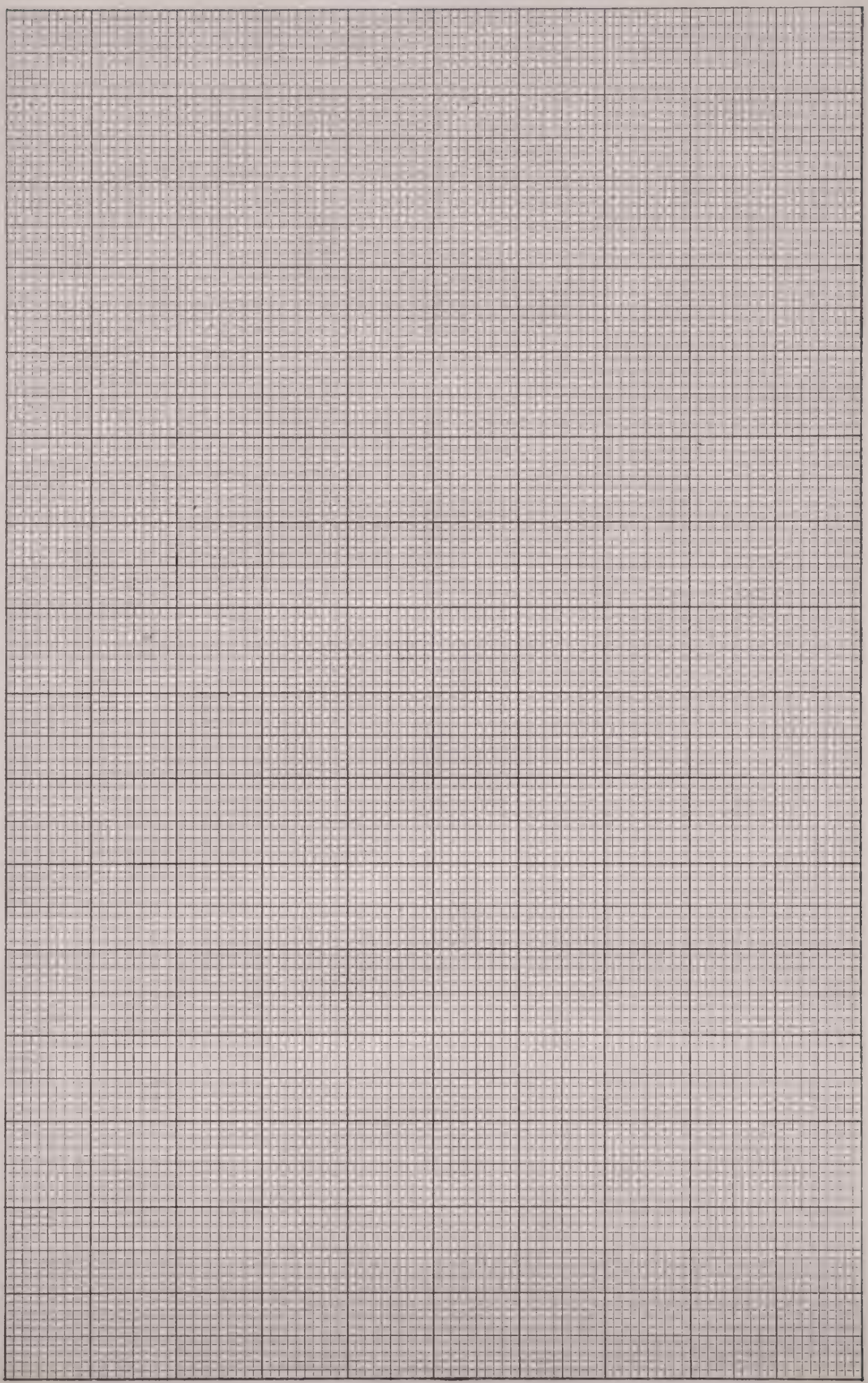


Cable Measurements

IT is customary to measure current ratios in telephone engineering by referring to a standard mile of cable for a comparison. The loss of current in the cable for any number of miles from 1 to 70 for audio frequencies may be determined from the chart below. Current ratio values are given as a fraction of the current in the line at the reference point.

Thus, if an ammeter placed in a line upon which a frequency of 1000 cycles was flowing read one ampere at one point, and another ammeter was read connected in the line 30 miles (of standard cable) away, the second meter would read .027 ampere.





Transmission Formula

SEVERAL formulas have been proposed to determine the energy which may be received from a given transmitting station. The ones that have received the most prominence were devised by Austin and Cohen, of the Bureau of Standards, and by Fuller. The formulas have never been thoroughly tested on all wavelengths and there are many cases where practical results differ widely.

The following charts will enable experimenters to solve the various factors that enter. This may lead to devising modifications of the original formula to make it more universal, or to determining more accurately the dissipation constant.

The formula is as follows: $$\frac{I_2}{I_1} = 4.25 \frac{25}{R_2 \sqrt{1+\frac{\delta_1}{\delta_2}}} \cdot \frac{h_1 h_2}{\lambda d} \cdot e^{-\frac{.0015d}{\sqrt{\lambda}}}$$

The lengths referred to are in the metric system, but the charts have been based on the English system to simplify solutions (the one exception being the unit of wavelength, where the meter is still retained).

The formula contains three parts, each of which will be solved with a separate chart. The first factor, F_1, deals with the resistance of the receiving set and the decrements of the transmitter and receiver. This factor is of little importance in comparison with the others and may be omitted if desired. The formula will not hold in the case of undamped waves. Solutions may be obtained with chart on page 111.

The second factor, F_2, is equal to $\frac{h_1 h_2}{\lambda d}$. The chart is operated as follows: "h_1" and "h_2" are the effective heights of the sending and receiving antenna respectively, measured in feet. The wavelength is measured in meters and the distance "d" in miles.

Select a value on scale 1 equal to the number of miles between the two stations. On the antenna height scale in the center select a point corresponding to the height of the transmitting antenna. Find where a straight line between these two points will intersect axis 1. Similarly select another point on the same antenna height scale to represent the effective height of the receiving antenna and a point on the wavelength scale corresponding to wavelength and find where a line between these points intersects axis 2.

Then a third line connecting the points on the axes so determined will intersect the F_2 scale near the center of the chart and indicate the value of this factor.

A solution has been indicated by the dotted lines. In actual operation, however, the lines need not be drawn in. In this problem h_1=200 feet, h_2=100 feet, distance=900 miles with a wavelength of 600 meters. The value of $F_2 = 2.9 \times 10^{-6} = .000,0029$.

The third factor "f" is an exponential factor suggested by Dr. Cohen. It represents the percentage of the energy that leaves the transmitter that reaches the receiving antenna. It is in the form of this factor that scientists differ and several have been suggested.

The dissipation factor with the value .0015 is used for normal conditions at night over water. This value differs when the surface over which the wave travels is partially or all land.

A solution may be obtained from page 115. When the constant .0015 is to be used select a point on scale 1 to correspond to the wavelength, and on scale 5 to correspond to the distance in miles. A line between these points will intersect the "f" scale (the fourth scale) to indicate the solution. Thus, f=.025 at a distance of 1500 miles with a 956 meter wave as indicated by key 1 on the chart. For long distances and short wavelengths the factor becomes very small and only the order of the value can be determined with the chart. More accurate values in this case can only be determined with 6 place logarithmic tables.

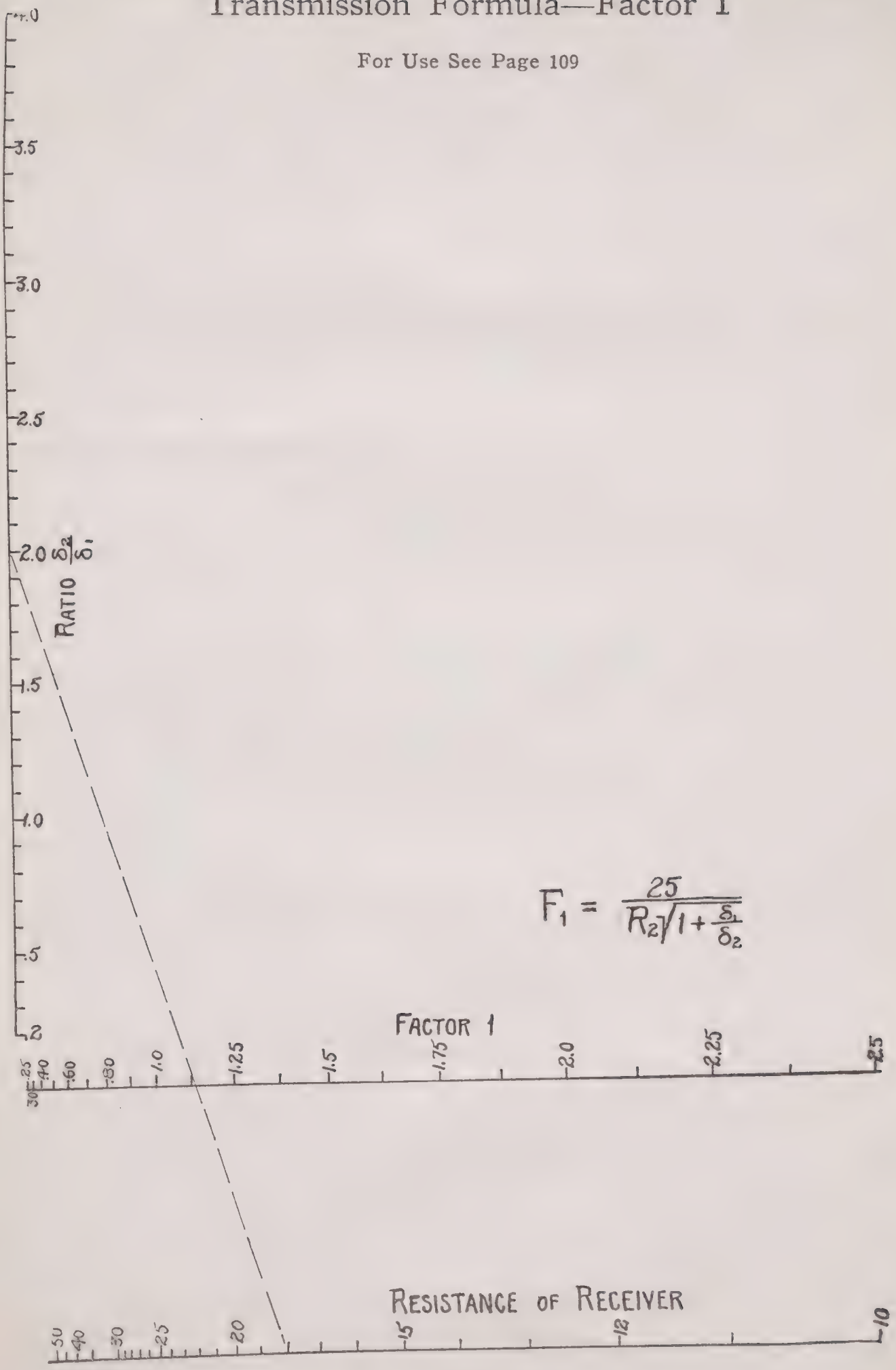
For another value of α besides .0015, select the value to be used on the center scale, and the distance on scale 2. Extend the line that cuts these two points until it reaches the distance scale (5). This operation is indicated by key a, for α=.0045 and distance=900 miles. The intersection with the scale 5 is at 2700 miles. From this latter point (see key b) a line drawn to the wavelength scale, to the point corresponding to the wavelength used, will intersect the "f" scale to indicate the solution as before. To complete the problem started with key a; for a wavelength of 450 meters the value of "f" indicated is .000,055.

Another exponential factor "f" has been proposed by Fuller that differs from the Cohen factor. A separate chart has been included for the former. Both charts are used in the same way.

A complete solution for the equation may be obtained since $I_2 = 4.25\, I_1\, F_1\, F_2\, f$.

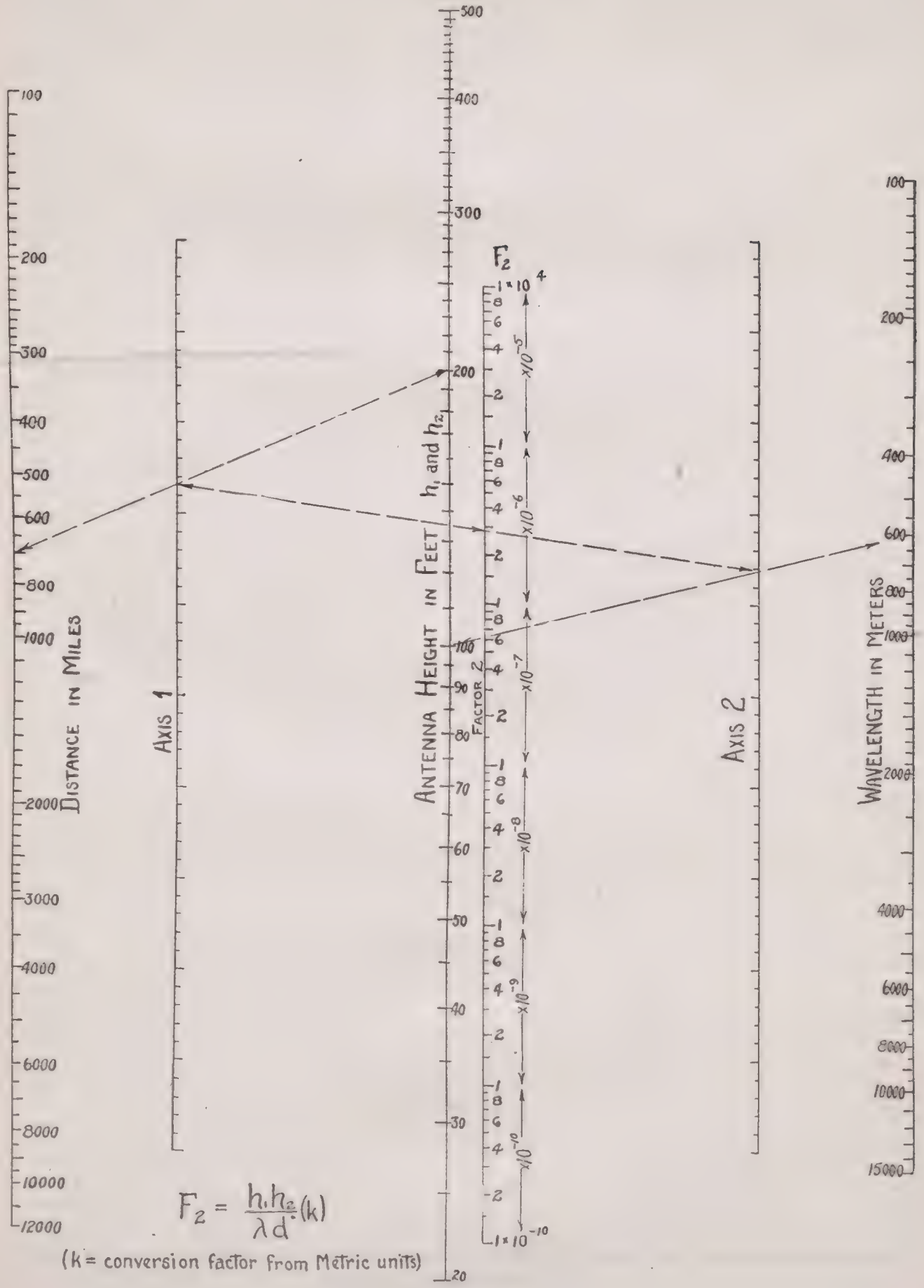
Transmission Formula—Factor 1

For Use See Page 109



Transmission Formula—Factor 2

For Use See Page 109



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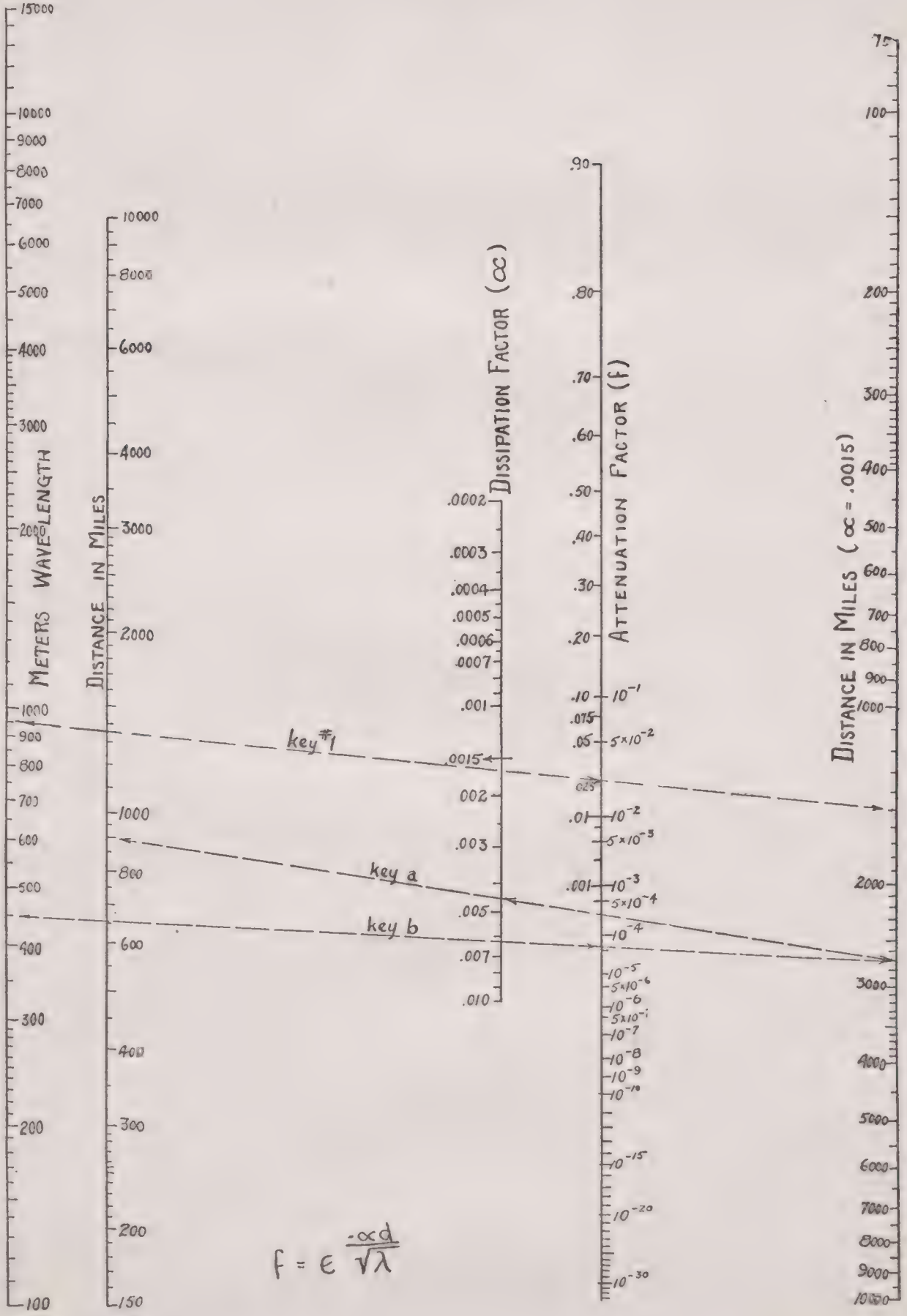
Austin-Cohen Transmission Formula—Attenuation Factor

For Use See Page 109



Transmission Formula—Fuller's Attenuation Factor

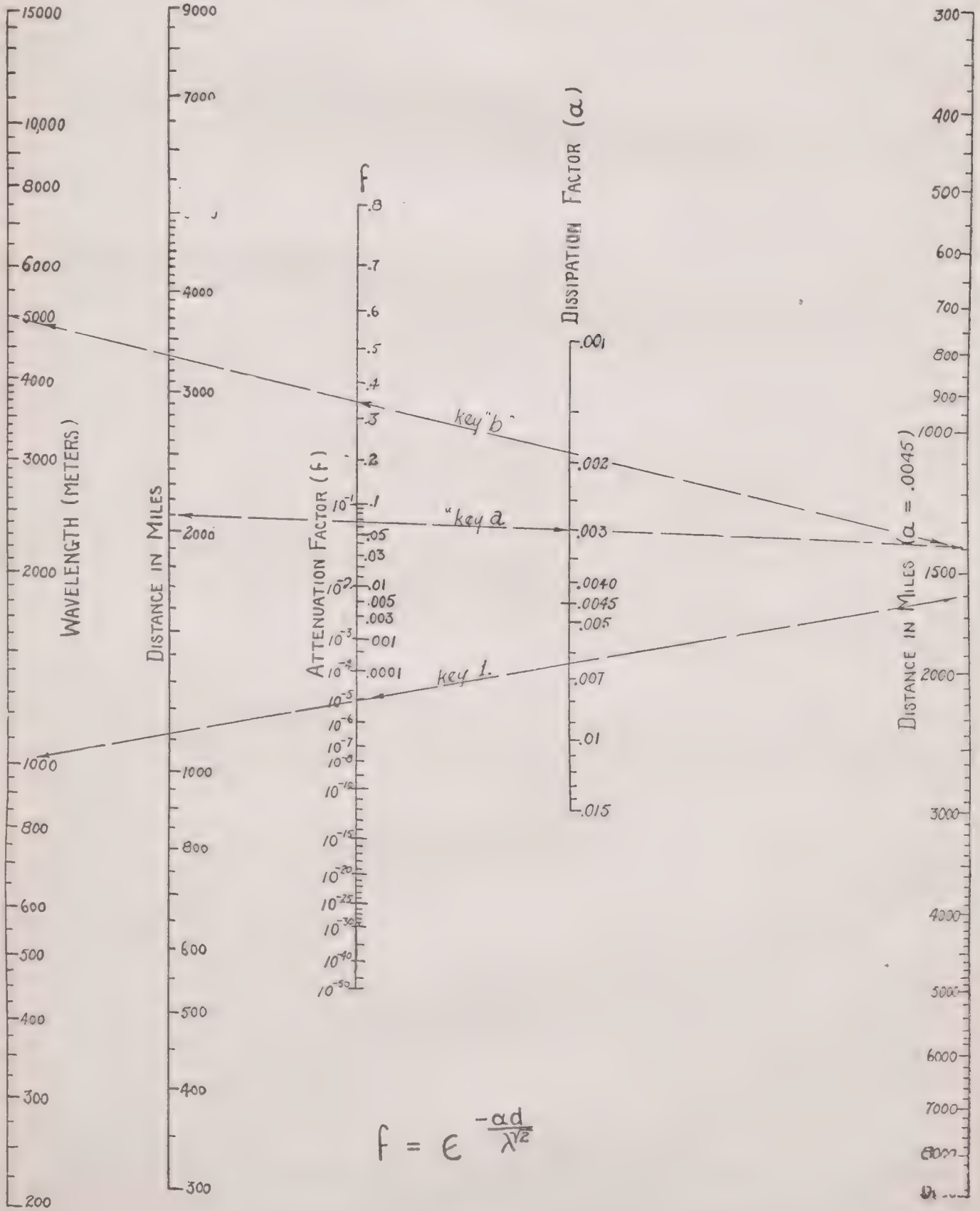
For Use See Page 109.

Method: If a=.0045 (suggested value due to Mr. Fuller) use scales 1, 3 and 5, as shown by key 1.

Example: Wavelength=1000 meters, d=1600 miles, then $f=9.5\times10^{-6}$.

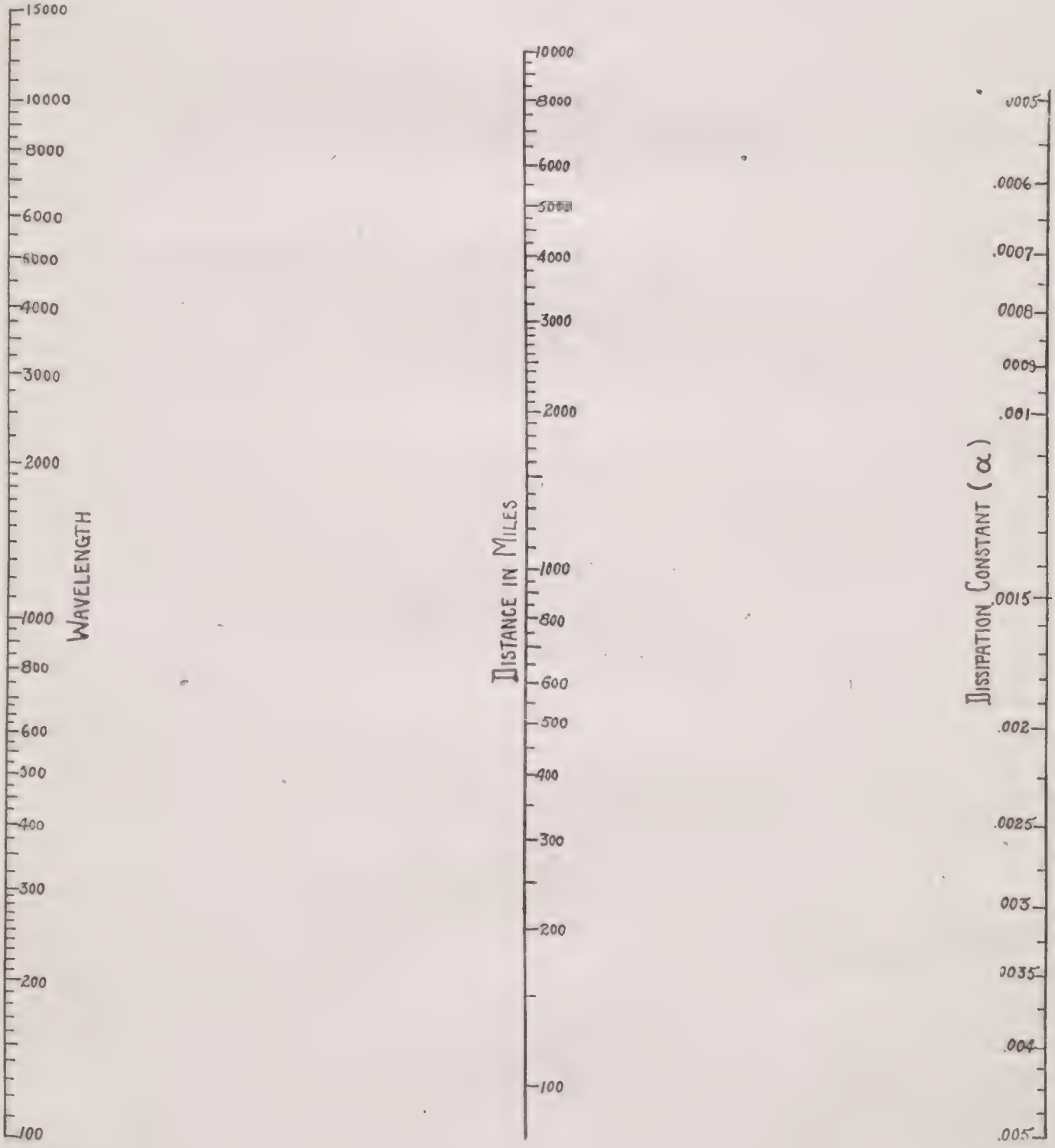
If a=any value between .001 and .015, first apply rule to scales 2, 4 and 5, as shown by key a. Then apply key b from the point so located on the distance scale to the wavelength scale.

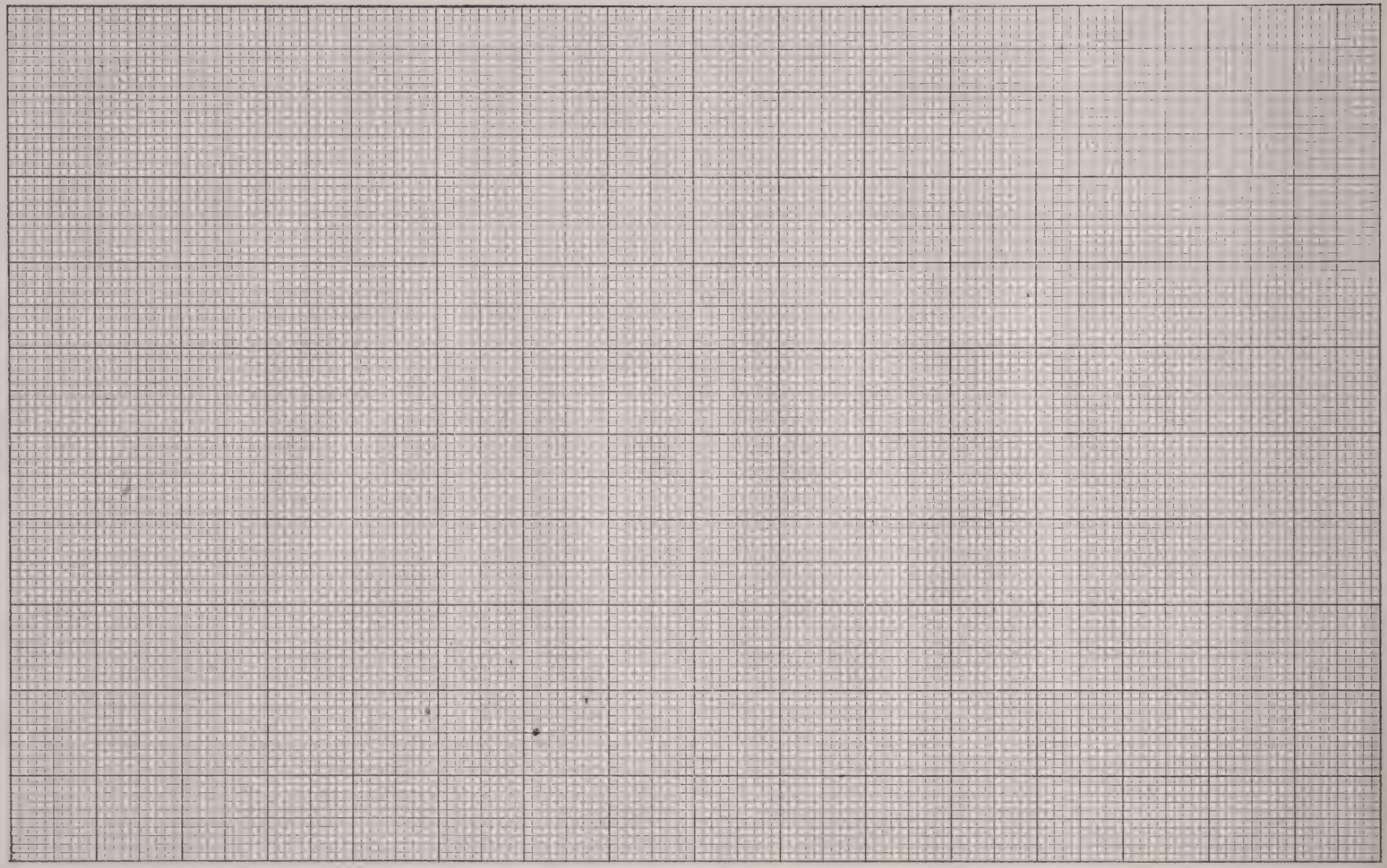
Example: a=.003, d=2100 miles, wavelength=5000 meters, then f=.35 (keys "b" and "a").



Optimum Wavelength to Cover a Given Distance

IF the form of the exponential factor in the Austin-Cohen transmission formula is assumed to be correct, the best wavelength to use to transmit any given distance may be determined. The following chart gives a wide range of values for the dissipation constant a. on scale 3. Distance values in miles are found on scale 2. and the wavelength on scale 1.





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USEFUL TABLE FOR DETERMINING THE WAVE LENGTH, FREQUENCY AND OSCILLATION CONSTANT OF RADIO FREQUENCY CIRCUITS

λ = wave-length in meters.

λ^2 = wave-length squared.

n = number of oscillations per second.

O = $\sqrt{LC}$ and is called the oscillation constant.

C = capacity in microfarads.

L = inductance in centimeters (1,000 cms. = 1 microhenry).

D = difference of L C for 1 meter.

λ	λ^2	n	O or $\sqrt{LC}$	L C	D
100	10,000	3000000	1.68	2.82	.042
110	12,100	2727272	1.80	3.24	.084
120	14,400	2500000	2.02	4.08	.067
130	16,900	2307600	2.18	4.75	.077
140	19,600	2142600	2.35	5.52	.083
150	22,500	2000000	2.52	6.35	.081
160	25,600	1874800	2.68	7.16	.096
170	28,900	1764600	2.85	8.12	.10
180	32,400	1666600	3.02	9.12	.105
190	36,100	1578800	3.19	10.17	.112
200	40,000	1500000	3.36	11.29	.11
210	44,100	1428400	3.52	12.39	.123
220	48,400	1363500	3.69	13.62	.128
230	52,900	1304200	3.86	14.90	.134
240	57,600	1250000	4.03	16.24	.131
250	62,500	1200000	4.19	17.55	.146
260	67,600	1153800	4.36	19.01	.15
270	72,900	1111000	4.53	20.52	.157
280	78,400	1071300	4.70	22.09	.163
290	84,100	1034300	4.87	23.72	.158
300	90,000	1000000	5.03	25.30	.174
310	96,100	967700	5.20	27.04	.18
320	102,400	937400	5.37	28.84	.185
330	108,900	909100	5.54	30.69	.18
340	115,600	882300	5.70	32.49	.197
350	122,500	857100	5.87	34.46	.20
360	129,600	833300	6.04	36.48	.208
370	136,900	810800	6.21	38.56	.215
380	144,400	789400	6.38	40.71	.206
390	152,100	769200	6.54	42.77	.226

λ	λ^2	n	O or $\sqrt{LC}$	LC	D
400	160,000	750000	6.71	45.03	.23
410	168,100	731700	6.88	47.33	.237
420	176,400	714300	7.05	49.70	.228
430	184,900	697700	7.21	51.98	.248
440	193,600	681800	7.38	54.46	.254
450	202,500	666700	7.55	57.00	.26
460	211,600	652200	7.72	59.60	.265
470	220,900	638300	7.89	62.25	.255
480	230,400	625000	8.05	64.80	.277
490	240,100	612200	8.22	67.57	.282
500	250,000	600000	8.39	70.39	.288
510	260,100	588200	8.56	73.27	.277
520	270,400	576900	8.72	76.04	.299
530	280,900	566000	8.89	79.03	.305
540	291.600	555600	9.06	82.08	.311
550	302,500	545400	9.23	85.19	.317
560	313,600	535700	9.40	88.36	.303
570	324,900	526300	9.56	91.39	.328
580	336,400	517200	9.73	94.67	.334
590	348,100	508500	9.90	98.01	.340
600	360,000	500000	10.07	101.41	.324
610	372,100	491800	10.23	104.65	.35
620	384,400	483900	10.40	108.15	.358
630	396,900	476200	10.57	111.73	.362
640	409,600	468800	10.74	115.35	.346
650	422,500	461500	10.90	118.81	.373
660	435,600	454600	11.07	122.54	.380
670	448,900	447800	11.24	126.34	.385
680	462,400	441200	11.41	130.19	.391
690	476,100	434800	11.58	134.10	.373
700	490,000	428600	11.74	137.83	.403
710	504,100	422500	11.91	141.86	.407
720	518,400	416700	12.08	145.93	.414
730	532,900	411000	12.25	150.07	.394
740	547,600	405400	12.41	154.01	.426
750	562,500	400000	12 58	158.27	.430
760	577,600	394800	12.75	162.57	.426
770	592,900	389600	12.92	166.83	.443
780	608,400	384600	13.09	171.35	.432
790	624.100	379800	13.25	175.57	.453
800	640,000	375000	13.42	180 10	.459
810	656,100	370400	13.59	184.69	.464
820	672,400	365900	13.76	189.33	.472
830	688,900	361400	13.93	194.05	.448
840	705,600	357100	14.09	198.53	.482

λ	λ^2	n	$\frac{O}{\text{or}}$ $\sqrt{LC}$	LC	D
850	722,500	352900	14.26	203.35	.489
860	739,600	348800	14.43	208.24	.493
870	756,900	344800	14.60	213.17	.469
880	774,400	340900	14.76	217.86	.504
890	792,100	337100	14.93	222.90	.511
900	810,000	333300	15.10	228.01	.516
910	828,100	329700	15.27	233.17	.492
920	846,400	326100	15.43	238.09	.527
930	864,900	322600	15.60	243.36	.534
940	883,600	319100	15.77	248.70	.538
950	902,500	315800	15.94	254.08	.545
960	921,600	312500	16.11	259.53	.518
970	940,900	309300	16.27	264.71	.567
980	960,400	306100	16.44	270.38	.552
990	980,100	303000	16.61	275.90	.567
1000	1000,000	300000	16.78	281.57	.543
1010	1020,100	297030	16.94	287.00	.570
1020	1040,400	294120	17.11	292.70	.590
1030	1060,900	291260	17.28	298.60	.590
1040	1081,600	288450	17.45	304.50	.60
1050	1102,550	285710	17.62	310.50	.56
1060	1123,600	283010	17.78	316.10	.61
1070	1144,900	280370	17.95	322.20	.61
1080	1166,400	277780	18.12	328.30	.62
1090	1188,100	275230	18.29	334.50	59
1100	1210,000	272730	18.45	340.40	.63
1110	1232,100	270270	18.62	346.70	.64
1120	1254,400	267850	18.79	353.10	.64
1130	1276,900	265480	18.96	359.50	.65
1140	1299,600	263150	19.13	366.00	.61
1150	1322,500	260860	19.29	372.10	.66
1160	1345,600	258610	19.46	378.70	.66
1170	1368,900	256400	19.63	385.30	.68
1180	1392,400	254230	19.80	392.10	.67
1190	1416,100	252100	19.97	398.80	.64
1200	1224,000	250000	20.13	405.20	.69
1210	1464,100	247930	20.30	412.10	.69
1220	1488,400	245900	20.47	419.00	.70
1230	1512,900	243900	20.64	426.00	.66
1240	1537,600	241930	20.80	432.60	.71
1250	1562,500	240000	20.97	439.70	.72
1260	1587,600	238090	21.14	446.90	.72
1270	1612,900	236220	21.31	454.10	.69
1280	1638,400	234370	21.47	461.00	.73
1290	1664,100	232560	21.64	468.30	.74

λ	λ^2	n	$\frac{O}{\text{or}}$ $\sqrt{LC}$	LC	D
1300	1,690,000	230760	21.81	475.70	.74
1310	1,716,000	229010	21,98	483.10	.75
1320	1,742,400	227270	22.15	490.60	.72
1330	1,768,900	225560	22.31	497.80	75
1340	1,795,600	223870	22.48	505.30	.77
1350	1,822,500	222220	22.65	513.00	.78
1360	1,849,600	220590	22.82	520.80	.73
1370	1,876,900	218970	22.98	528.10	.78
1380	1,904,400	217390	23.15	535.90	.79
1390	1,932,100	215830	23.32	543.80	.80
1400	1,960,000	214380	23.49	551.80	.80
1410	1,988,100	212760	23.66	559.80	.76
1420	2,016,400	211260	23.82	567.40	.81
1430	2,044,900	209790	23.99	575.50	.82
1440	2,073,600	208340	24.16	583.70	.82
1450	2,102,500	206900	24.33	591.90	.79
1460	2,131,600	205470	24.49	599.80	.83
1470	2,160,900	204080	24.66	608.10	.84
1480	2,190,400	202700	24.83	616.50	.85
1490	2,220,100	201340	25.00	625.00	.80
1500	2,250,000	200000	25.17	633.50	.81
1510	2,280,100	198680	25.33	641.60	.86
1520	2,310,400	197360	25.50	650.20	.88
1530	2,340,900	196070	25.67	659.00	.87
1540	2,371,600	194800	25.84	667.70	.83
1550	2,402,500	193540	26.00	676.00	.89
1560	2,433.600	192310	26.17	684.90	.89
1570	2,464,900	191060	26.34	693.80	.90
1580	2,496,400	189860	26.51	702.80	.90
1590	2,528,100	188670	26.68	711.80	.86
1600	2,560,000	187500	26.84	720.40	.91
1610	2,592,100	186340	27.01	729.50	.92
1620	2,624,400	185190	27.18	738.70	.93
1630	2,656,900	184050	27.35	748.00	.93
1640	2,689,600	182930	27.52	757.30	.89
1650	2,722,500	181820	27.68	766.20	.94
1660	2,755,600	180730	27.85	775.60	.96
1670	2,788,900	179640	28.02	785.20	.94
1680	2,822,400	178570	28.19	794.60	.91
1690	2,856,100	177510	28.35	803.70	.97
1700	2,890,000	176460	28.52	813.40	.97
1710	2,924,100	175440	28.69	823.10	.98
1720	2,958,400	174420	28.86	832.90	.93
1730	2,992,900	173410	29.02	842.20	.98

λ	λ^2	n	$\frac{O}{\text{or}}$ $\sqrt{LC}$	LC	D
1740	3,026,600	172410	29.19	852.00	1.00
1750	3,062,500	171430	29.36	862.00	1.00
1760	3,097,600	170450	29.53	872.00	1.00
1770	3,132,900	169490	29.70	882.10	.95
1780	3,168,400	168540	29.86	981.60	1.02
1790	3,204,100	167600	30.03	901.80	.92
1800	3,240,000	166670	30.20	912.00	1.03
1810	3,276,100	165750	30.37	922.30	1.04
1820	3,312,400	164840	30.54	932.70	.98
1830	3,348,900	163940	30.70	942.50	1.05
1840	3,385,600	163040	30.87	953.00	1.04
1850	3,422,500	162160	31.04	963.40	1.06
1860	3,459,600	161290	31.21	974.10	1.00
1870	3,496,900	150430	31.37	984.10	1.07
1880	3,534,400	159370	31.54	994.80	1.08
1890	3,572,100	158730	31.71	1005.60	1.08
1900	3,610,000	157890	31.88	1016.40	1.02
1910	3,648,100	157060	32.04	1026.60	1.09
1920	3,686,400	156240	32.21	1037.50	1.10
1930	3,724,900	155440	32.35	1048.50	1.14
1940	3,763,600	154630	32.55	1059.90	1.07
1950	3,802,500	153840	32.72	1070.60	1.05
1960	3,841,600	153060	32.88	1081.10	1.12
1970	3,880,900	152280	33.05	1092.30	1.12
1980	3,920,400	151510	33.22	1103.50	1.14
1990	3,960,100	150750	33.39	1114.90	1.07
2000	4,000,000	150000	33.55	1125.60	1.15
2010	4,040,100	149250	33.72	1137.10	1.25
2020	4,080,400	148520	33.89	1149.60	1.05
2030	4,120,900	147780	34.06	1160.10	1.16
2040	4,166,600	147060	34.23	1171.70	1.10
2050	4,202,500	146340	34.39	1182.70	1.17
2060	4,243,600	145630	34.56	1194.40	1.18
2070	4,284,900	144930	34.73	1206.20	1.18
2080	4,326,400	144230	34.90	1218.00	1.18
2090	4,368,100	143540	35.07	1229.80	1.14
2100	4,410,000	142850	35.23	1241.20	1.20
2110	4,452,100	142180	35.40	1253.20	1.21
2120	4,494,400	141510	35.57	1265.30	1.21
2130	4,536,900	140840	35.74	1277.40	1.15
2140	4,579,600	140180	35.90	1288.90	1.22
2150	4,622,500	139540	36.07	1301.10	1.23
2160	4,665,600	138880	36.24	1313.40	1.23
2170	4,708,900	138240	36.41	1325.70	1.24
2180	4,752,400	137610	36.58	1338.10	1.17
2190	4,796,100	136980	36.74	1349.80	1.26

λ	λ^2	n	O or $\sqrt{LC}$	LC	D
2200	4,840,000	136360	36.91	1362.40	1.25
2210	4,844,100	135740	37.08	1374.90	1.26
2220	4,928,400	135130	37.25	1387.50	1.19
2230	4,972,900	134530	37.41	1399.40	1.28
2240	5,017,600	133930	37.58	1412.20	1.29
2250	5,062,500	133330	37.75	1425.10	1.29
2260	5,107,600	132740	37.92	1438.00	1.22
2270	5,152,900	132160	38.08	1450.20	1.29
2280	5,198,400	131570	38.25	1463.10	1.31
2290	5,244,100	131000	38.42	1476.20	1.31
2300	5,290,000	130430	38.59	1489.30	1.31
2310	5,336,100	129870	38.76	1502.40	1,32
2320	5,382,400	129310	38.93	1515.60	1.25
2330	5,428,900	128750	39.09	1528.10	1.33
2340	5,475,600	128200	39.26	1541.40	1.33
2350	5,522,500	127660	39.43	1554.70	1.34
2360	5,569,600	127120	39.60	1568.10	1.27
2370	5,616,900	126580	39.76	1580.80	1.37
2380	5,644,400	126050	39.93	1594.50	1.35
2390	5,712,100	125520	40.10	1608.00	1.45
2400	5,760,000	125000	40.27	1621.80	1.45
2410	5,808,100	124480	40.45	1636.30	1.21
2420	5,856,400	123960	40.60	1648.40	1.39
2330	5,904,900	123450	40.77	1662.30	1.38
2440	5,953,600	122950	40.94	1676.10	1.39
2450	6,002,500	122450	41.11	1690.00	1.33
2460	6,051,600	121950	41.27	1703.30	1.40
2470	6,100,900	121450	41.44	1717.30	1.41
2480	6,150,400	120960	41.64	1731.40	1.40
2490	6,200,100	120480	41.78	1745.40	1.43
2500	6,250,000	120000	41.95	1759.70	1.36
2510	6,300,100	119520	42.11	1773.30	1.42
2520	6,350,400	119050	42.28	1787.50	1.45
2530	6,400,900	118580	42.45	1802.00	1.44
2540	6,451,600	118120	42.62	1816.40	1.46
2550	6,502,500	117650	42.79	1831.00	1.38
2560	6,553,600	117190	42.95	1844.80	1.46
2570	6,504,900	116730	43.12	1859.40	1.46
2580	6,656,400	116280	43.29	1874.00	1.47
2590	6,708,100	115830	43.46	1888.70	1.39
2600	6,760,000	115380	43.62	1902.60	1.49
2610	6,812,100	114940	43.79	1917.50	1.48
2620	6,864,400	114510	43.96	1932.30	1.51
2630	6,916,900	114070	44.13	1947.40	1.42

λ	λ^2	n	$\frac{O}{\text{or}}$ $\sqrt{LC}$	LC	D
2640	6,969,600	113640	44.29	1961.60	1.50
2650	7,022,500	113210	44.46	1976.60	1.51
2660	7,075,600	112780	44.63	1991.70	1.53
2670	7,128,900	112360	44.80	2007.00	1.53
2680	7,182,400	111940	44.97	2022.30	1.43
2690	7,236,100	111530	45.13	2036.60	1.54
2700	7,290,000	111110	45.30	2052.00	1.54
2710	7,344,100	110700	45.47	2067.40	1.56
2720	7,398,400	110290	45.64	2083.00	1.47
2730	7,452,900	109890	45.80	2097.70	1.54
2740	7,507,600	109490	45.97	2113.10	1.58
2750	7,562,500	109090	46.14	2128.90	1.58
2760	7,617,600	108700	46.31	2144.70	1.48
2770	7,672,900	108300	46.47	2159.50	1.57
2780	7,728,400	107920	46.64	2175.20	1.59
2790	7,784,100	107530	46.81	2191.10	1.59
2800	7,840,000	107140	46.98	2207.00	1.60
2810	7,896,100	106760	47.15	2223.00	1.62
2820	7,952,400	106380	47.32	2239.20	1.52
2830	8,008,900	106010	47.48	2254.40	1.62
2840	8,065,600	105630	47.65	2270.60	1.63
2850	8,122,500	105260	47.82	2286.90	1.62
2860	8,179,600	104890	47.99	2303.10	1.54
2870	8,236,900	104530	48.15	2318.50	1.64
2880	8,294,400	104170	48.32	2334.90	1.64
2890	8,352,100	103810	48.49	2351.30	1.50
2900	8,410,000	103450	48.66	2366.30	1.80
2910	8,468,100	103090	48.83	2384.30	1.47
2920	8,526,400	102740	48.99	2399.00	1.77
2930	8,584,900	102390	49.16	2416.70	1.69
2940	8,643,600	102040	49.33	2433.60	1.67
2950	8,702,500	101700	49.50	2450.30	1.58
2960	8,761,600	101350	49.66	2466.10	1.69
2970	8,820,900	101010	49.83	2483.00	1.70
2980	8,880,400	100660	50.00	2500.00	1.71
2990	8,940,100	100320	50.17	2517.00	1.61
3000	9,000,000	100000	50.33	2533.20	1.69
3025	9,150,625	99170	50.75	2575.60	1.71
3950	9,302,500	98560	51.17	2618.40	1.72
3075	9,455,625	97560	51.59	2661.50	1.74
3100	9,610,000	96770	52.01	2705.10	1.75

λ	λ^2	n	$\frac{O}{\text{or}}$ $\sqrt{LC}$	LC	D
3125	9,765,625	96000	52.43	2748.90	1.76
3150	9,922,500	95230	52.85	2793.10	1.78
3175	10,080,625	94490	53.27	2837.80	1.79
3200	10,240,000	93750	53.69	2882.70	1.80
3225	10,400,625	93020	54.11	2927.90	1.83
3250	10,562,500	92310	54.53	2973.70	1.83
3275	10,725,625	91600	54.95	3019.60	1.84
3300	10,890,000	90910	55.37	3065.80	1.87
3325	11,055,625	90220	55.79	3112.60	1.87
3350	11,222,500	89550	56.21	3159.50	1.90
3375	11,280,625	88890	56.63	3207.10	1.90
3400	11,560,000	88230	57.05	3254.80	1.86
3425	11,730,625	87590	57.46	3301.60	1.93
3450	11,902,500	86960	57.88	3350.00	1.95
3475	12,075,625	86330	58.30	3398.90	1.96
3500	12,250,000	85720	58.72	3448.00	1.98
3525	12,425,625	85100	59.14	3497.50	1.99
3550	12,602,500	84510	59.56	3547.40	2.01
3575	12,780,625	89310	59.98	3597.70	2.01
3600	12,960,000	83330	60.40	3648.10	2.03
3625	13,140,625	82750	60.82	3699.00	2.04
3650	13,322,500	82190	61.24	3750.20	2.07
3675	13,505,625	81630	61.66	3802.00	2.07
3700	13,690,000	81090	62.08	3853.80	2.09
3725	13,875,625	80540	62.50	3906.20	2.10
3750	14,062,500	80000	62.92	3958.80	2.12
3775	14,250,625	79470	63.34	4012.00	2.16
3800	14,440,000	78950	63.76	4065.00	2.16
3825	14,630,625	78430	64.18	4119.00	2.16
3850	14,822,500	77920	64.60	4173.00	2.20
3875	15,015,625	77420	65.02	4228.00	2.12
3900	15,210,000	76930	65.43	4281.00	2.20
3925	15,405,625	76440	65.85	4336.00	2.24
3950	15,602,500	75950	66.27	4392.00	2.24
3975	15,800,625	75470	66.69	4448.00	2.24
4000	16,000,000	75000	67.11	4504.00	2.28
4025	16,200,625	74540	67.53	4561.00	2.24
4050	16,402,500	74080	67.95	4617.00	2.32
4075	16,605,625	73620	68.37	4675.00	2.28
4100	16,810,000	73170	68.79	4732.00	2.32

λ	λ^2	n	$\frac{O}{or}$ $\frac{}{\sqrt{LC}}$	LC	D
4125	17,015,625	72730	69.21	4790.00	2.32
4150	17,222,500	72290	69.63	4848.00	2 32
4175	17,430,625	71850	70.05	4907.00	2.36
4200	17,640,000	71430	70.47	4966.00	2.40
4225	17,850,625	71010	70.89	5026.00	2.36
4250	18,062,500	70590	71.31	5085.00	2.40
4275	18,275,625	70180	71.73	5145.00	2.44
4300	18,490,000	69770	72.15	5206.00	2.40
4325	18,705,625	69370	72.57	5266.00	2.48
4350	18,922.500	68970	72.99	5328.00	2.40
4375	19.140.625	68580	73.40	5388.00	2 52
4400	19,360,000	68190	73.83	5451.00	2.40
4425	19,580,625	67800	74.24	5511.00	2.52
4450	19,802,500	67420	74.66	5574.00	2.52
4475	20,025,625	67040	75.08	5637.00	2.52
4500	20,250,000.	66670	75.50	5700.00	2 56
4525	20,475.625	66300	75.92	5764.00	2.52
4550	20,702,500	65940	76.34	5827.00	2.60
4575	20,930,625	65580	76.76	5892.00	2.60
4600	21.160.000	65220	77.18	5957.00	2.52
4625	21,390.625	64870	77.60	6020.00	2.68
4650	21,622,500	64520	78.02	6087.00	2.64
4675	21,855.625	64170	78.44	6153.00	2.64
4700	22,090.000	63830	78.86	6219.00	2.64
4725	22,325.625	62490	79.28	6285.00	2.68
4750	22,562,500	63160	79.70	6352.00	2.68
4775	22,800,625	62830	80.12	6419.00	2.64
4800	23,040,000	62500	80.53	6485.00	2.72
4825	23,280,625	62180	80.95	6553.00	2.72
4850	23,522,500	61860	81.37	6621.00	2.76
4875	23,765,625	61540	81.79	6690.00	2.76
4900	24,010,000	61230	82.21	6759.00	2.76
4925	24,255,625	60910	82.63	6828.00	2.76
4950	24,502,500	60610	83.05	6897.00	2.80
4975	24,750,625	60300	83.47	6967.00	2.84
5000	25,000,000	60000	83.89	7038.00	

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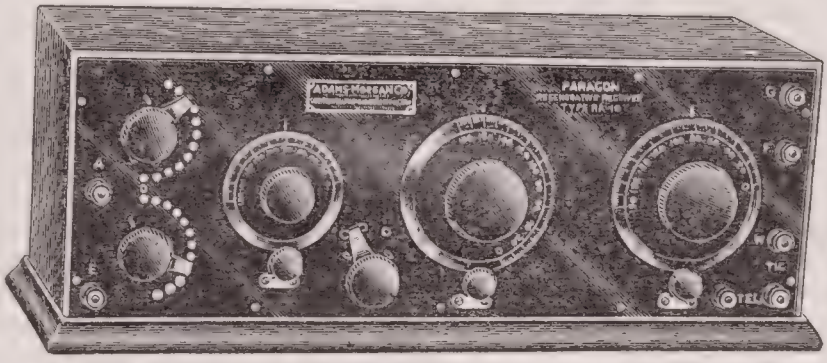

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